THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA. 1912.

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JOURNAL

OF

The Academy of Natural Sciences

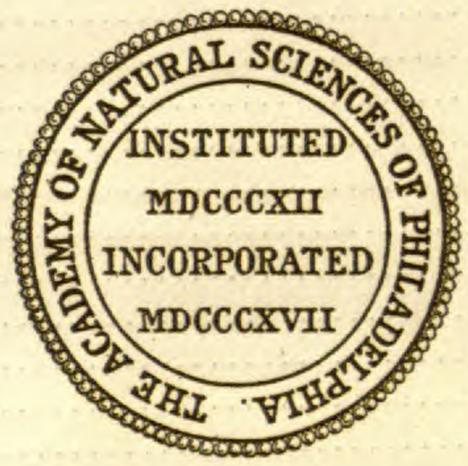
OF

Philadelphia

Second Series, Volume XV.

PUBLISHED IN COMMEMORATION OF THE ONE HUNDREDTH ANNIVERSARY
OF THE FOUNDING OF THE ACADEMY, MARCH 21, 1912

1812



1912

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DATES OF PUBLICATION.

Extra copies of the contents of this volume have been issued as follows:—

Proceedings of the Centenary Meeting	December 7, 1912.
President's Address	December 4, 1912.
Montgomery	December 4, 1912.
Maury	December 4, 1912.
Clarke	December 4, 1912.
Skinner	September 7, 1912.
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EDWARD J. NOLAN,
Recording Secretary.

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

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I.

Proceedings of the Centenary Meeting, March 19, 20, and 21, 1912.

PROCEEDINGS.

INTRODUCTION.

Early in January, 1911, the Recording Secretary in letters to the President and the Chairman of the Library Committee, urged the desirability of a fitting observance of the one hundredth anniversary of the foundation of the Academy. He prepared an outline program which, having been elaborated by a preliminary committee consisting of Henry G. Bryant, LL.B., George Vaux, Jr., Henry Skinner, M.D., Sc.D., Thomas H. Fenton, M.D., and the Secretary, was approved by the Council, the proposed celebration was authorized, and the President was directed to appoint a Committee of Arrangements of which he should be the Chairman.

The President appointed a general committee, which, appropriately divided into sub-committees, was charged with the details of management as follows:

CENTENARY COMMITTEES.

HONORABLE SAMUEL GIBSON DIXON, M.D., LL.D., President of the Academy, Chairman of the General Committee.

EDWARD J. NOLAN, M.D., Recording Secretary and Librarian of the Academy, Secretary of the General Committee.

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MEETINGS AND ADDRESSES.

Thomas H. Fenton, M.D.
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George Vaux, Jr.
Spencer Trotter, M.D.
Edwin G. Conklin, A.M., Ph.D., Sc.D.
Thomas L. Montgomery
James M. Anders, M.D.

INVITATIONS.

J. Percy Moore, Ph.D.
John Cadwalader, A.M., LL.D.
W. W. Keen, M.D., LL.D.
George McClellan, M.D.
G. de Schweinitz, A.M., M.D.
H. Sellers Colton, A.M., Ph.D.
Thomas H. Montgomery, Ph.D.

ENTERTAINMENT.

Robert G. LeConte, M.D.
Albert P. Brubaker, M.D.
Edwin I. Simpson
Henry Tucker, M.D.
Hon. Charlemagne Tower
Roland G. Curtin, M.D.
Francis E. Bond
Witmer Stone, A.M.
Daniel M. Barringer
Herbert Fox, M.D.
Henry Winsor, M.D.
Francis X. Dercum, M.D., Ph.D.
William D. Winsor
Thomas G. Ashton, M.D.
Walter Horstmann
Charles Z. Tryon

FINANCE.

Hon. Samuel Gibson Dixon, M.D., LL.D.
George Vaux, Jr.
Edwin S. Dixon
George S. Morris
Walter Horstmann
Henry G. Bryant, LL.B.
John Cadwalader, A.M., LL.D.

A formal announcement of the occasion was mailed in January, 1912, to correspondents and scientific institutions throughout the world by the Corresponding Secretary, J. Percy Moore, Ph.D.:—

The Academy of Natural Sciences of Philadelphia founded in the year eighteen hundred and twelve for the cultivation of the natural sciences, in March, nineteen hundred and twelve, will have completed one hundred years of active devotion to this purpose.

For the adequate celebration of its centenary anniversary the Academy will call in convention at its Hall the learned men and institutions of the world—its collaborators.

The Academy has the honor to invite . . . . . to be present at this event, which will take place at Philadelphia on Tuesday, Wednesday, and Thursday, the nineteenth, twentieth, and twenty-first of March, nineteen hundred and twelve.

As will be seen from the letters published in connection with the proceedings, the responses have been most gratifying. Many of these documents are beautiful specimens of illumination and chirography. The appointment of one hundred and forty-seven delegates by corresponding societies and institutions was also a demonstration of the practical interest taken by the scientific world in the occasion.

Cablegrams and letters of congratulation and appreciation continued to be received after the commemorative meeting had adjourned.

On the recommendation of the Publication Committee it was decided to issue in connection with the celebration an Index to the complete series of the PROCEEDINGS and JOURNAL, a detailed history of the Academy, and a commemorative quarto volume (the fifteenth of the JOURNAL) to consist of the Proceedings of the Sessions and a collection of adequately illustrated memoirs contributed by members and correspondents.

The sessions extended over three days: the 19th, 20th, and 21st of March. The first was held on the evening of Tuesday, the 19th, because that was the time of the stated meeting of the Academy, but the 21st was the actual date of the anniversary.

The meetings were held, not as usual in the Reading Room, but in the Lecture Hall which afforded more ample accommodation and which was well filled on the occasion of the opening session, the front seats being occupied by delegates.

On the platform were seated the President, the Mayor of the City, the two Vice-Presidents, the Corresponding and Recording Secretaries, and Sir James Grant, the representative of the Royal Society of Canada.

The weather Wednesday morning was bright, sparkling, and genial, but that of Thursday was in violent and undesirable contrast, a fall of snow being driven along by a penetrating wind. It was a most gratifying evidence of the earnestness and interest of those in attendance that but little decrease in their number was observable when the meeting was called to order.

The announcement of the death of Thomas Harrison Montgomery was a pathetic incident of the opening session. As stated in the memorial note preceding his paper Dr. Montgomery had been deeply interested in the arrangements for the celebration and was the first one to hand in a contribution to this commemorative volume. It had been arranged that he should read the first paper on Thursday morning, but instead of hearing the voice which many present loved so well, the Chair announced that his funeral would take place the following morning from St. Mary's Church, West Philadelphia.

The midday luncheons provided on Wednesday and Thursday were thoroughly enjoyed and furnished the opportunity for social intercourse which was generally taken advantage of.

A brilliant reception was given as part of the anniversary celebration by the President, Mrs. Dixon, and Miss Dixon at the Bellevue-Stratford Hotel on the evening of the 20th. It was attended by upwards of fifteen hundred invited guests, the Philadelphians being manifestly delighted to meet the Academy's correspondents and delegates. A charmingly sociable tone prevailed during the evening and the occasion will long be remembered by those present as a most enjoyable feature of the program.

The indispensable banquet was also a brilliant success, owing to the discretion and good taste of the Chairman of the Committee on Entertainment, Dr. Robert Grier LeConte, who had the cooperation of Dr. Henry Tucker and Dr. Thomas G. Ashton. The luncheons and the banquet were served in the New Hall, the preparation of which in time for such service was due to the executive ability of the President and the energy of his Secretary, Edwin I. Simpson. The system of lighting produced the effect of a soft diffused illumination as pleasant as daylight. It imparted full value to the floral and other beautiful decorations.

Thanks to the cooperation of those best able to judge of the value of the work accomplished, the general success of the Centenary Celebration was commensurate with the influence exerted by the Academy on the development of the natural sciences during the past one hundred years.

EDWARD J. NOLAN,
Recording Secretary.

April 8, 1912.

PROCEEDINGS OF THE SESSIONS.

TUESDAY, MARCH 19, 1912.

The meeting was called to order promptly at 8 P. M., the President, the HONORABLE SAMUEL GIBSON DIXON, M.D., LL.D., in the Chair.

The Recording Secretary requested the delegates, as the names of the societies and institutions represented by them were called by the Corresponding Secretary, to arise and hand their letters of credential and congratulation to the President without reading. As the exercises of the evening were likely to be lengthy, he asked, if remarks were considered desirable, that they should be brief. Thus advised, as a matter of fact no one spoke, and as much the greater number of the letters had already been delivered by mail, this otherwise tedious part of the program was not unduly prolonged.

The President, introducing the HONORABLE RUDOLPH BLANKENBURG, the Mayor of the City of Philadelphia, remarked:—

Science never makes such rapid strides as when we are governed by progressive, intelligent men, who appreciate education and the work of original research. We are to be congratulated on having such a man with us tonight and it is my especial privilege to present to you the Honorable Rudolph Blankenburg, Mayor of the City of Philadelphia.

Mr. Blankenburg spoke as follows:

THE MAYOR'S ADDRESS.

Mr. President, Delegates, Ladies and Gentlemen: It is a pleasure for me to appear this evening before a body of scientific men and scientific women, and to be relieved for a little while of the cares of office and especially to be able, in a few words, to welcome you on this auspicious occasion. I am little of a scientist myself, but I have always appreciated science and those interested in scientific investigations. If it were not for such institutions as the Academy we would not be nearly as far advanced in learning and civilization as we are. Everything pertaining to the enlightenment of mankind naturally leads to the development of knowledge, of ideals, and to an evolution of truth, a higher character, and higher aims in life.

From what I learn, The Academy of Natural Sciences of Philadelphia stands at the head of similar institutions in this country. This is hardly to be wondered at, because we are at the head and front of so many things in America that this is only one small additional token of what Philadelphia does, of what Philadelphians have done, and of what Philadelphians can do, if they will. The collections within the walls of this beautiful building are among the best to be found in our country. The building itself is conveniently located and easy of access—in fact it is so convenient to my house (living, as I do, only half a square, or a stone's throw away) that I have not been within its walls for ten years. I am really almost ashamed to make this confession. If the Academy of Natural Sciences were a hundred or five hundred, or a thousand miles from Philadelphia, I am sure that I should have visited it on numerous occasions.

In looking over the history of the Academy of Natural Sciences, I learn that it was founded one hundred years ago by a few young, intelligent, and public-spirited men, who met at first in their private homes, and gradually grew in number and interest until The Academy of Natural Sciences of Philadelphia, from its small origin, erects a proud head to-day. I mention this simply as showing how great things spring from the very smallest causes: I believe this is a scientific maxim. If the few men who organized the Academy could look down upon what has been accomplished in one hundred years, they would certainly feel amply repaid in the thought that their work has been well done.

Look at the Philadelphia of a hundred years ago. The city itself then had only 53,722 inhabitants. To-day that part of the city which then comprised the whole of Philadelphia has but 89,357 inhabitants; there has hardly been any growth at all. The men who founded this great Academy hardly knew how well they were building. Philadelphia was at that time only a small place; the whole of the city was not much larger in area than the adjoining Fifteenth Ward. Gleaning from the past, should the work of old not be an incentive to people living to-day, whenever the opportunity offers, to build likewise? Many important undertakings had their origin in a small way. Never let us despise small things, my friends, but encourage all those who desire to do something for the progress of the world. It may sometimes seem idle to encourage their ambition; but even a seemingly small effort in laboring for the good of mankind and the welfare of the community should be encouraged.

Your great institution to-day stands as one of the landmarks of Philadelphia. It is being visited by hundreds and thousands of people every week: and since, through the unceasing efforts and the genius of your President, Dr. Dixon, you have secured at last this great building, one of the finest homes of its kind in this country, with so much accomplished, I am sure the future of this organization is assured. Doctor Dixon tells me that there is a fund to-day which gives you fifty thousand dollars a year for the maintenance of the wonderful collection housed in this building, and that not one cent of the Academy's capital was touched for the great improvements that have been made within the last few years.

I do not intend to make a speech. My purpose is to welcome you—to welcome you gentlemen and you ladies who come from a distance to the City of Brotherly Love. You know of Philadelphia's hospitality. Everything will be open to you. We shall be glad to take you to the great and renowned places of which only Philadelphia can boast. There may be some among you who have not even seen Independence Hall. If there be any let me know, and I shall be glad to take you there to-morrow morning so that you may be able to say, on your return home, "I have seen Independence Hall: I have visited the Cradle of Liberty." I welcome all of you, ladies and gentlemen, whether from home or abroad, and let this meeting be the forerunner of even greater success for this great institution for all the centuries to come.

After announcements by the Secretary the President delivered an historical address as follows:

THE PRESIDENT'S ADDRESS.

Fellow Members and Guests: This is one of the occasions which stimulate reflection. To-day we must all feel a regret that we cannot inherit the learning of those who have gone before us. So keen an appreciation do I possess of the unselfish devotion of my predecessors to science and to this institution, and so impressed am I at the monthly meetings in our Reading Room by their faces looking down upon us from their respective canvases hanging on the walls, that my feelings impel me to call upon them in spirit to join me in extending to our guests the heartiest of welcomes and to say that we, the present workers, fully appreciate how much credit is due them for our present success.

To-day this City of Brotherly Love, with the mother Commonwealth, Pennsylvania, in common with the great union of states, is at peace with all the nations of the globe. This blessed condition did not prevail on the day when our forefathers assembled one hundred years ago, to organize an institution for the study and advancement of the Natural Sciences. During the last days of the year 1811, the dispute between the United States and Great Britain and the doubt as to the attitude of France seemed to indicate that the national honor was hurt and that another contest with a European power was at hand. The commerce of the country had suffered. The Committee on Foreign Relations recited the wrongs that the United States had sustained from Great Britain, and declared it to be the sacred duty of Congress to call forth the patriotism and resources of the country. Extensive military measures were recommended. The Pennsylvania Legislature passed acts for enlarging the regiment of artillery and for the organization of the cavalry of the city of Philadelphia. Although war was not declared until June, 1812, in anticipation of the necessities of the situation Congress approved a loan of eleven million dollars, of which one million six hundred and forty-five thousand dollars were raised in Philadelphia.

Large meetings of people were held all over the city to consider the needs of commercial interests and to pass resolutions for the equipment of privateers and for building up the defences of the city.

The legislature relieved the tension of its patriotic resolutions by requesting a special committee to examine a machine made by Charles Redhefer, who claimed that it possessed the power of self motion, and naively stated that "if the machine be found to be imperfect the public interest will be promoted by exposing its fallacy."

In the midst of excitements due to impending war the youth of the city naturally sought the taverns and oyster cellars as meeting places, as indeed there was little in the way of diversion provided for the people of that period. The theater was seldom opened, and the feeling against it was so strong that a petition was presented to the legislature requesting it to abolish forever the exhibition of "Theatricles." Peale's Museum enjoyed great popularity, and here the *lusus*

naturæ were in steady demand. The calf with five legs vied for public favor with the child without ears.

Notwithstanding the preparations for war which were draining the resources of all men the founders of this institution had such faith in the future of the United States of America that they did not hesitate even with the din of martial demonstrations in their ears and the consciousness of an awful, impending struggle with gigantic powers in their minds, to proceed quietly, methodically, and unperturbed to found an association for pure learning which has now become one of the foremost among the scientific institutions of the world.

The voices that started the vibrations whose echoes still resound in this Hall of Science, though no longer heard, are too numerous to be mentioned on this occasion, when there is so much that is new to be brought out within the short time allotted for this our last assembly in the Academy's first century.

The Academy was born of the enthusiasm of earnest lovers of science. They had before them a single purpose, the unveiling of some of the laws of nature and the engraving of them on the tablets of the society that they might be studied by men of all nations. To accomplish this great end as the society grew they realized the necessity of explorations, of collections, of laboratories, of a library, and of reciprocity with bodies having similar aims.

In the beginning of the nineteenth century a few young men in this city spent their spare time in studying natural history. They soon learned it was to their mutual interest to compare their notes. In the year 1812 John Speakman and Jacob Gilliams agreed that it would be well to hold regular meetings; accordingly they, with Dr. Gerard Troost, Nicholas S. Parmentier, Dr. Camillus Macmahon Mann, and John Shinn, Jr., met at the home of one of their members on the northwest corner of Market and 2d Sts., on January 25, 1812. Thomas Say was almost immediately added to their number. The minutes of this meeting set forth that their object would be the rational disposition of otherwise leisure moments. Their next assembly was held at a public house on Market Street near Franklin Place on the 21st day of March, 1812, at which time Dr. Samuel Jackson, of the University of Pennsylvania, is said to have suggested the title of The Academy of Natural Sciences. The collection of the society at this time was represented by a few common insects, a few corals and shells, a dried toad fish, and a stuffed monkey.

Thus established, the Academy, with its constantly increasing resources, has been for one hundred years administered for the benefit of all students of natural history.

Masters of science have come from all parts of the world to consult the great zoological, botanical, geological, and ethnological collections which the accumulated labors of our members, during a century of activity, have brought together in the museum.

Writers and students of all grades have come to consult the great natural history library which the liberality of our members and the worldwide exchange of our publications have enabled us to place on the shelves.

Pupils from schools have come under the guidance of their teachers to study and profit by the exhibits displayed in our public museum halls, while our specialists have delivered courses of popular lectures on the natural sciences under the auspices of the Academy and the Ludwick Institute.

In every way within its power the Academy has promoted for a century the study of the natural sciences, advanced or elementary, pure or applied.

The one hundredth anniversary is a particularly happy birthday because our precious natural history library, unexcelled in America, and our priceless collections of mammals, birds, reptiles, fishes, shells, insects, plants, ethnological and geological specimens, unsurpassed in several of the departments and in all of them rich in the type specimens of the early naturalists of America, having been for almost one hundred years exposed to the danger of damage or destruction by fire are now, with the intelligent cooperation of the Commonwealth of Pennsylvania, placed in a thoroughly fireproof building.

The society has, however, never received state or city financial aid for maintenance, but has depended entirely upon the liberality of intelligent people, mainly of Philadelphia, for the necessary funds to purchase land for our buildings, to publish the results of the scientific researches of our members, to fit out expeditions, and of late years to pay meager salaries to the members of the scientific staff.

While we have thus built up world-renowned study collections it has been impossible to develop the popular exhibits that sister institutions, rich in state and municipal appropriations, have been enabled to install.

We have, however, kept our collections systematically arranged and have, during the last decade, had the satisfaction of seeing all the historical types and study series placed in metal cases, impervious to light, dust or moth, thus insuring them the longest possible life.

Our corresponding membership now numbers about two hundred, composed only of the greatest scientists of the period.

Biographical sketches of our officers and scientific workers who carried us through the last one hundred years are recorded in our publications and as we have so little time before us they can only be casually alluded to in this brief resumé of the Academy's history. We are, however, proud of the escutcheon upon which the history of their lives is engraved.

Members of this Academy have taken a very prominent part in explorations. Thomas Say was a member of Long's Expedition to the Rocky Mountains in 1819 and 1820 and was one of the first scientific men to become personally acquainted with the vast natural history resources of the great West.

Nuttall and Townsend, thirty years after the Lewis and Clark Expedition, crossed the continent to the mouth of the Columbia River, and extended their explorations to the Hawaiian Islands, returning around the Horn. They brought home rarities of animal and plant life, many of which were unknown to science. These collections were placed in the Academy's museum, then the chief repository for natural history specimens in America, and here they are still preserved.

When the United States government was organizing the famous Wilkes Expedition of 1838, the Academy was requested to nominate its scientific staff and two of its members eventually accompanied the party.

In the year 1850 one of our members, Edward Harris, financed and accompanied the great Audubon expedition up the Missouri River. Through his modesty, we were prevented at the time from making known the important part that he took in this expedition. Other members made possible the work of DuChaillu in equatorial Africa.

We provided Dr. Kane with his outfit for systematic collecting in 1853, when he made his Arctic exploration. To-day we have many specimens obtained by him. Specially interesting is the gigantic stuffed polar bear which stands in interesting contrast to the modern mounted specimen brought here by the Peary Relief Expedition.

The Hayes exploration of the far north a few years later was also aided and endorsed by the Academy.

Rear Admiral Peary, discouraged by his futile attempts to interest other institutions and governments in his proposed voyage of exploration to the north, came to us with his proposition. He was generously received and a committee was appointed to arrange the expedition, which sailed on June 6, 1891 from Brooklyn, under the auspices of the Academy, to explore the Arctic regions. On January 26, 1892, a relief party was organized under the command of Professor Heilprin. On September 24, 1892, it returned with the explorers, sailing up the Delaware River on the now historic vessel "Kite."

Peary did not reach the highest latitude on his first expedition. His aim was accomplished in showing that Greenland was an island by tracing its northernmost line. It was during his next trip, which was not under the auspices of the Academy of Natural Sciences, that he made his northernmost record previous to his polar dash.

If the Academy had not taken an interest in Peary when he was about discouraged, the chances are he would never have planted the American flag at the north pole.

Dr. Hayden, a member of the Academy, when conducting the United States Geological Survey in the west, made up his scientific parties largely from our membership. The setting apart of the great national Yellowstone Park resulted from his numerous explorations. Every three years this institution bestows upon a distinguished geologist the Hayden Gold Medal, an award which was founded by Dr. Hayden's widow.

The Pennsylvania Geological Surveys were also conducted by members of Academy: Rogers and Lesley.

Our colleagues, Leidy and Cope, were the first to describe the extinct animals from the wonderful deposits of the western states.

I may mention among the more recent expeditions those of Professor Heilprin to Yucatan and Mexico in 1890; Harrison and Hiller to Sumatra; Samuel

N. Rhoads to British Columbia, the Colorado River, and Ecuador; Donaldson Smith to Somaliland and Lake Rudolph; and Francis E. Bond to Venezuela, from all of which we have received rich returns.

The publications of the Academy had early a world-wide reputation. For many years they furnished the only adequate means through which American scientists reached the naturalists of the world. Contributions of papers came from all parts of America. To-day our various publications are exchanged with all the nations of the civilized world. It may be interesting to state here the fact that when the famous Pacific railroad surveys were made, the United States government published descriptions of all the new species it obtained in the PROCEEDINGS of the Academy.

Passing rapidly over the more important departments of our museum, we find among mammals a number of the specimens obtained by Townsend in the far West, made known to science in the JOURNAL by our correspondents Audubon and Bachman; the Harrison Allen collection of bats, the Rhoads collection of North American mammals, and the splendid collection of anthropoid apes presented by Dr. Thomas Biddle.

The collection of birds will ever stand as a memorial to two of our members: Thomas B. Wilson and John Cassin. To Dr. Wilson's liberality we owe the acquirement of the famous Rivoli collection, the Gould collection, and many others. His entire gift, comprising some 25,000 specimens, was regarded in 1857 as the finest collection in the world. Cassin spent his life in the study of this material and his researches published in the PROCEEDINGS made the Academy famous as an ornithological center the world over, while he himself stood preeminent among the ornithologists of America.

The part that the Academy played in the development of ornithology in America may be appreciated by the mere mention of those who worked within its walls or published the results of their researches in the PROCEEDINGS: Nuttall, Bonaparte, Townsend, Gambel, Heerman, Harris, and Woodhouse, among our members, and Baird, Lawrence, and Coues, among our correspondents.

In our vast series of reptiles, we find the material collected and studied by Hallowell, Cope, and Brown—names inseparable from the history of herpetology in America.

In the study of fishes at the Academy the names of Bonaparte and Cope, already mentioned in other connections, stand forth prominently and their collections are still carefully preserved. Charles LeSueur, one of our earliest members, also attained fame as an ichthyologist, while of late years several of those who studied at the Academy have become famous in the service of the Unites States Fish Commission—notably, the late John Adam Ryder.

The Academy has from its foundation taken a prominent part in the study of the mollusca and has accumulated a collection probably second to none. A series of investigators, eminent in their special field, have made the society one of the world centers in this department of science.

Almost a century ago Thomas Say blazed the trail for conchologists, while Dr. Isaac Lea and Timothy Abbott Conrad were his successors. Lea's work, largely published by the Academy, is the basis of all later systematic study of fresh water mussels, while to Conrad we owe the foundation of American tertiary geology and paleontology, his work in this line overshadowing that on the living mollusca. Gabb was another famous worker in this field, while to George W. Tryon, Jr., we owe the conception of the *Manual of Conchology*, begun by him in 1878 and continued by the Academy after his death in 1888. Very few works have led to so many reforms in classification or have had such a broad influence as this. Dr. Joseph Leidy, who may be termed the Cuvier of America, should be mentioned in this connection because of his fine contribution to Binney's *Terrestrial Air-breathing Mollusks of the United States*, published in 1851. This was the first American work on the morphology of the soft parts of the mollusks.

Thomas Say, already referred to as a pioneer conchologist, is also known as the father of American entomology. Owing to his energy, the Academy's collection in this department was begun—a collection which by steady growth has reached a total of a million specimens and has become of world-wide renown. The long list of entomologists who have contributed to its development, contains the names of most of those whose activities constitute the earlier history of entomology in America.

Titian R. Peale, Wilson, LeConte, Horn, McCook, Cresson, Martindale, and others have made our entomological department one of the most important in America. The Cresson collection of hymenoptera has made the Academy the greatest in America in this particular branch. The Bassett collection of galls and gall insects is the most comprehensive ever brought together.

In palæontology the names of Leidy and Cope are preeminent. *The Extinct Mammalian Fauna of Dakota and Nebraska*, published by Dr. Leidy as the seventh volume of the JOURNAL, is a classic. Students of paleontology still come to consult the types of his descriptions, which are preserved in our collection.

Professor Cope's part in the development of American paleontology is too well known to require detailed mention and was carried on side by side with his studies of reptiles and fishes, in which his reputation was equally great. Even on his death-bed he placed the finishing touches to his report on the Pleistocene remains discovered at Port Kennedy, Pennsylvania, a paper which attracted the attention of the paleontological world and which appeared in the JOURNAL of the Academy soon after his death.

In botanical research the Academy has always held an important place and its herbarium, now numbering some 900,000 specimens, contains the types of such pioneers as Nuttall, Pursh, Muhlenberg, and deSchweinitz, besides comprehensive collections from all parts of the globe. Among those whose researches have been carried on at the Academy may be mentioned in addition to the above, Durand, Charles E. Smith, Meehan, and Redfield.

In anthropology the works of Morton and later of Harrison Allen are famous. The splendid collection of human crania brought together by the former is historic. Archeological and ethnological collections comprise the material gathered by Samuel Stehman Haldeman in North America and in the land of the Aztecs, Mayas, and Incas.

There are also the Wm. S. Vaux collection rich in specimens of the neolithic age of Europe, the Robt. H. Lamborn collection and the Clarence B. Moore collection.

Mr. Moore's collection embodies the results of more than twenty years' exploration in the southern United States and consists of thousands of specimens of the vanished art industries of our southern aborigines now saved for all time in the museum and in the fine series of reports published in the JOURNAL.

We have extensive mineral collections, foremost among which is that of William S. Vaux, noted for the beauty of its specimens and the completeness of the series.

There are the famous Febiger collection of diatoms, the Chapman study series of marine animals, and others which lack of time forces me to pass over.

So too there are many other former members of the Academy who by their scientific attainments or their loyal and generous support have helped to build up the institution, while among the living members are men who are, by their work and devotion, fully as deserving of notice as those who have gone before.

Helmholtz, in 1862, said, "In fact men of science form, as it were, an organized army, laboring on behalf of the whole nation, and generally under its direction and at its expense, to augment the stock of such knowledge as may serve to promote industrial enterprise, to increase wealth, to adorn life, to improve political and social relations, and to further the moral development of individual citizens. After the immediate practical results of their work we forbear to inquire; that we leave to the uninstructed. We are convinced that whatever contributes to the knowledge of the forces of nature or the powers of the human mind is worth cherishing, and may, in its own due time, bear practical fruits, very often where we should least have expected it."

It has been truly said that the distinctive feature of pure science is that "it is not remunerative; the practical rewards and returns are not the immediate ends in view." The work of Tyndall and Pasteur, however, on fermentation, pursued in the beginning purely because of its abstract scientific interest, later came to have enormous economic importance and led to the scientific investigations that have within recent years become of incalculable value to mankind.

The knowledge gathered by the abstract naturalist and the tabulation of scientific data concerning all forms of animal and vegetable life have a very close and direct relation to public health and preventive medicine. A long list of diseases might be compiled in which insects are directly responsible for the transmission of the bacterium or parasite life causing disease. It is now a matter of almost universal knowledge that malarial fever is transmitted from

man to man by means of the *Anopheles* mosquito, that the yellow fever virus can only be transmitted through the *Stegomyia calopus*, that the bubonic plague may be carried from man to man or from rat to man by means of the rat flea (*Pulex cheopis*), that the *Trypanosoma gambiense* of African sleeping sickness can be communicated only by means of the tsetse-fly, that the organism causing human filariasis is transmitted by the *Culex fatigans* and certain species of *Anopheles*, and evidence is gradually accumulating that the bacterium of leprosy is transmitted through the bed-bug, *Cimex lectularius*. A knowledge of the natural history of these insects was absolutely essential for the scientific study of the diseases with which they are so closely associated and public health work has only been effective in eradicating the disorders in proportion to the efforts of the sanitarian directed toward their destruction and for the protection of the individual. The entomologist, the zoologist, and the bacteriologist are each required to contribute their share in the research that means so much to public health and to mankind. If much has already been accomplished, still greater are the fields open for scientific investigation.

With the lower forms of animal life parasitic to man and known to cause disease, the connecting link, the intermediate host, the full life history are missing in many instances where it would seem that the most fertile field for the scientist has not yet been invaded. A very large province lies open for those who undertake a careful study of the relation between the vermes and the human being. Much indeed has been learned about parasites inhabiting the intestinal canal, but the parasitologist has not yet concluded the final analysis of the life history of many of these forms.

The work of the Academy has been so distinctly pure science that the lay public have not until recently appreciated the great practical relationship it has to health and economics. The description of the various species, their life history, their geographical range, have enabled those working in applied sciences to conduct the already successful war against the enemies of man, of the lower animals, and of plant life.

Let it be remembered that in 1793 half the population of Philadelphia either died from yellow fever, or voluntarily exiled themselves to escape from the scourge, that all the southern tier of states were kept in a state of constant terror every summer for fear of its invasion, causing a loss of millions to the commerce of the country, and then recall the fact that through entomological and medical cooperation this disease was practically eliminated from Cuba, its breeding place for ages, and that in 1905, a violent epidemic of the same plague was actually checked in New Orleans by the application of the knowledge gleaned by the medical department of our army in the more southern field.

That mysterious blight to human life and energy known as malaria, to which, as much as to the fire and sword of northern barbarians Greece and Rome owed their downfall, has been traced to its entomological source so that these two devastating diseases have ceased to be a menace to civilized communities,

allowing that great work, the construction of the Panama canal, heretofore impossible owing to their prevalence, to go on uninterruptedly under conditions of unparalleled health. The sacrifice of 5,000 American troops during the Spanish-American war, was finally found to have been due to the transmission of *Bacillus typhosus* by the common house fly, and this knowledge has been so judiciously applied by our army surgeons that a recent considerable mobilization of our soldiers was entirely exempt from that disease, conveying some faint conception of the immense debt that humanity owes to the patient workers in the field of pure science.

Economic entomology, based upon abstract work, shows an annual money loss in the United States of North America occasioned by insects amounting to $1,272,000,000.

The congratulatory letters, with the autographs of our foreign co-workers, received from the great institutions of the world relating to this our one hundredth birthday, cannot be read owing to a want of time, but will be recorded in our Commemorative Volume.

Before closing I have a pleasant duty to perform on behalf of the Building Committee. At the request of those entrusted with planning and erecting the improvements made possible by the Commonwealth of Pennsylvania, and as Chairman of the Committee, I hand over to the corporate body, under the title of The Academy of Natural Sciences of Philadelphia, this building completed for its use, comprising fireproof stacks for its library, a reading room, lecture hall, and work rooms.

In the rhythmic language of another I reverently invoke the blessings of the God of Nature upon this temple of the Natural Sciences.

Great God of nature, let these halls
  The hidden things of earth make plain;
Let knowledge trumpet forth her calls,
  And wisdom speak, but not in vain.

Help us to read with humble mind
  Thy larger scriptures day by day —
True bread of life! O be thou kind,
  If, erring, we should go astray.

For deep resounding unto deep,
  Declares the wonders of thy plan;
Life struggling from its crystal sleep
  Finds glorious goal at last in man.

The mysteries of the eternal laws
  Are but the shadows of thy might.
God, ruling all in final cause,
  Enshrine the world in love and light!

Harvey Maitland Watts.

It was explained that the routine of a stated meeting would then go on, in the belief that an illustration of the formula by means of which the Academy had transacted its business as a society for one hundred years would be of interest to those familiar with the results which had made the celebration worth while.

At the call of the Chair the Recording Secretary read the minutes of the last meeting and the minute of the first Recording Secretary, Dr. Camillus Macmahon Mann, defining the date of foundation as follows:—

YEAR OF THE UNITED STATES THE 37TH.

Saturday, March 21, 1812.

In Committee agreed: The year of the institution shall commence at the present natural evolution: the spring equinox, 21st of March and the year shall be named according to the era of the United States of America in the principal city of which we assemble.

Additions to the museum and library were announced.

The Corresponding Secretary reported on letters received since the last meeting.

The Publication Committee, in conjunction with the Centenary Sub-committee on Printing and Publication, reported the titles of papers presented for consideration and also announced the details of works to be issued in connection with the celebration.

The Chair announced the death this morning of Thomas Harrison Montgomery, Jr., Ph.D.[1]

Under the head of "verbal communications" the Recording Secretary gave some "Reminiscences" of his fifty years' connection with the Academy as Assistant Librarian, Librarian, and Recording Secretary, his first list of accessions to the library being dated February 4, 1862.

It had been his intention to glance rapidly at a few of the interesting characters in the first half century of the Academy's history: such men as Maclure, Say, Troost, Lesueur, Morton, Correa da Serra, Bonaparte, and Keating, but the time at his disposal confined him to some of those he had personally known since 1862.

It was a cause of keenest regret that he had not recorded the recollections of a few of the contemporaries of the founders who still survived when he entered on the scene, but it could be readily believed that in the boy's most sanguine moments he had never entertained the thought that fifty years later, on the occasion of the Academy's Centenary, he would be called on to deplore his lack of foresight before such an audience.

He had seen George Ord, the biographer of Alexander Wilson and one of the ex-presidents, three or four times; Jacob Peirce, elected a member in 1813, two years before Ord; Isaac Hays, who had practically kept the early JOURNAL alive by his energy, tact, and zeal; Titian R. Peale, the intimate friend of Say and Maclure, all cordially willing to talk of the early days.

Dr. Nolan then spoke of the beginning of his work as an untrained assistant in the library and the unvarying kindness and consideration he had experienced from all the men met with at the time but especially from his dear chief, J. Dickinson Sergeant, and his beloved future preceptor, Joseph Leidy.

[1] See note in advance of memoir.

It was an extraordinary epoch in the history of the Academy, the beginning of its second half century, and the youth was associated with a stimulating group of men, including Leidy, Cope, Conrad, Tryon, Stewardson, Lea, Slack, Rand, Warner, Vaux, Cassin, Heerman, Meigs, Gabb, and Wilson, all men of marked individuality, many of whom had made permanent records as leaders of science in America.

Continuing, Dr. Nolan gave his impressions of some of his contemporaries of later date: Allen, Horn, LeConte, Meehan, Warner, Hawkins, Ruschenberger, Redfield, Ryder, McCook, Heilprin, Chapman, Isaac Jones Wistar, and Arthur Erwin Brown. He adopted a more intimate tone than would be desirable in a printed record in the belief that such confidences would not be objected to by his auditors, many of whom were familiar with the work of the men whom he was describing.[2]

In the one hundred years of the Academy's history four men had stood out prominently, with, of course, many associates, as dominant in its material and intellectual advancement. These were Thomas Say, Samuel George Morton, Joseph Leidy, and the present chief executive. The work of Say, Morton, and Leidy formed part of the history of the Academy, and if an impression were desired of the accomplishments of Samuel Gibson Dixon his auditors had but to look around them.

Closing his recollections the Secretary was distressed to remember the names of the many dear friends whom, for lack of time, he was forced to leave in the undesirable class "and others."

In conclusion he remarked:—

Those whom I knew during the first years of association with the Academy are nearly all dead. The old building, if it still existed, would be full of ghosts, and even in the present halls, in the dusk of the winter days, dear shades encounter me in the alcoves and passage ways and remind me of the time when I too shall be a recollection and a tradition.

But in the meantime it is with a feeling of profound gratitude that I bear testimony to the kindly patience and sustaining encouragement of those who are still with me and who relieve the daily task almost entirely of stress and strain.

For obvious reasons I cannot deal in personalities in the case of my living contemporaries, but I am at liberty to say that they are worthily taking the place of those who have labored so loyally for the advancement of the Academy and who, we are not forbidden by the highest reason to hope, are now rejoicing in this splendid commemoration of their labors. Had they lived when men cherished the same truths under different formulæ their motto, as I have said elsewhere, would have been, *Ad majorem Dei gloriam.*

May the men who come after us be as zealous and as disinterested in the development of truth as were those whom I have been so ineffectively remembering tonight, so that when the second Centenary is celebrated it also may be

[2] Much of this information and more of the same character will be found in Dr. Nolan's *History of the Academy*, to be published in connection with the Centenary Celebration.

the subject of congratulation from a like gathering of kindly and appreciative friends.

Nominations for membership were read, the elections of those formerly proposed being deferred until the following month.

The rough minutes were then read for criticism and approval as had been the custom for nearly one hundred years, the secretary explaining that he had complied with the directions of Dr. Mann and had dated the record as having been made in the 137th year of the United States.

No corrections being suggested, the minutes were adopted as read and the meeting adjourned until the following morning at 10 o'clock.

Wednesday Morning, March 20.

The hall was filled with delegates, members, and visitors, when the President dropped the gavel at 10 o'clock. The following papers, nearly all of which were resumés of communications which will form a portion of the second section of this volume, were then read:

Edwin G. Conklin, Ph.D., Sc.D., Vice-President of the Academy and Professor of Biology in the University of Princeton:

Experimental Studies of Nuclear and Cell Division.*[3]

Carlotta J. Maury, Ph.D., Lecturer on Paleontology in Barnard College, Columbia University:

A Contribution to the Paleontology of Trinidad.*

William J. Holland, Sc.D., LL.D., Director of the Carnegie Museum, Pittsburgh:

David Alter, the first Discoverer of Spectrum Analysis, with exhibition of the Prism used by him.*

John William Harshberger, Ph.D., Assistant Professor of Botany in the University of Pennsylvania:

The Vegetation of the Banana Holes of Florida.*

Frederick William True, M.S., LL.D., Assistant Secretary of the Smithsonian Institution:

A New Species of Delphinodon.*

Henry Herbert Donaldson, Sc.D., Ph.D., Professor of Neurology in the Wistar Institute of Anatomy and Biology.

The History and Zoological Position of the Albino Rat.*

Edward Browning Meigs, M.D., Fellow in Physiology in the Wistar Institute of Anatomy and Biology:

The Ash of Smooth Muscle.[4]

[3] An asterisk after the title of the paper indicates that an abstract has been published in advance in the *Proceedings of the Academy*, LXIV, 1912.

[4] The entire article is in *The Journal of Biological Chemistry*, May, 1912. This paper was prepared in association with Leon Alonzo Ryan, Ph.D., Associate Professor of Chemistry and Toxicology in the University of Pennsylvania.

MARSHALL AVERY HOWE, PH.D., Curator of the Museum of the New York Botanical Garden:

Reef-building and Land-forming Seaweeds, illustrated by views and specimens.*

At the conclusion of Dr. Howe's paper the audience adjourned to the New Hall — the old library hall transformed — where a liberal lunch was enjoyed.

The meeting reassembled at 2:30 P. M., when BENJAMIN SMITH LYMAN, former Chief Geologist of the Empire of Japan, read a paper entitled "Natural History Morality."[5]

It was followed by:

JACQUES LOEB, M.D., Sc.D., of the Rockefeller Institute for Medical Research:

Experiments on Adaptation of Animals to Higher Temperatures.

HENRY SKINNER, M.D., Sc.D., Curator of Entomology in The Academy of Natural Sciences of Philadelphia, Professor of Entomology in the Pennsylvania Horticultural Society:

Mimicry in Butterflies.*

SPENCER TROTTER, M.D., Professor of Natural History in Swarthmore College:

The Faunal Divisions of Eastern North America in Relation to Vegetation.*

T. WAYLAND VAUGHAN, PH.D., of the United States Geological Survey:

Rate of Growth of Stony Corals.

HENRY AUGUSTUS PILSBRY, Sc.D., Curator of Mollusca in The Academy of Natural Sciences of Philadelphia:

On the Tropical Element in the Molluscan Fauna of Florida.*

The session closed with illustrations by means of a collection of superb lantern views, of methods of photographing wild birds, by WILLIAM L. BAILY.

THURSDAY, MARCH 21.

The session was called to order by the President. The place assigned on the program to the late Dr. Montgomery was taken by EDWIN J. HOUSTON, PH.D., Professor of Physics in the Central High School of Philadelphia, who made an interesting communication on "How the Natural Sciences can be made Attractive to the Young."*

The following papers were then read:

JAMES A. G. REHN, Assistant in Entomology in The Academy of Natural Sciences of Philadelphia:

The Orthopteran Inhabitants of the Sonoran Creosote Bush.*

MERKEL H. JACOBS, PH.D., of the Wistar Institute of Anatomy and Biology:

Physiological Characters of Species.*

[5] *Proceedings of the Academy*, LXIV, March, 1912.

HENRY FAIRFIELD OSBORN, LL.D., Sc.D., Research Professor of Zoology in Columbia College, Curator Emeritus of the Department of Vertebrate Paleontology in the American Museum of Natural History:

Tetraplasy, or Law of the Four Inseparable Factors of Evolution.*

GEORGE HOWARD PARKER, Sc.D., Professor of Zoology in Harvard University:

Sensory Appropriation as illustrated by the Organs of Taste in Vertebrates.*

JOHN MUIRHEAD MACFARLANE, Sc.D., Professor of Botany in the University of Pennsylvania:

The Relation of Protoplasm to its Environment.*

WILLIAM HEALY DALL, A.M., Sc.D., Honorary Curator of Mollusca in the United States National Museum:

Mollusk Fauna of Northwest America.

After luncheon HENRY GRIER BRYANT, LL.B., President of the Geographical Society of Philadelphia, read a paper on Governmental Agencies in the Advancement of Geographical Knowledge in the United States, illustrated by maps and charts.*

The scientific sessions closed with a well-illustrated lecture by WITMER STONE, A.M., the Curator of Ornithology in The Academy of Natural Sciences of Philadelphia, on the Fauna and Flora of the New Jersey Pine Barrens.*

Announcing the adjournment the President remarked:

On behalf of the Members of The Academy of Natural Sciences of Philadelphia I assure you that we all appreciate the disadvantages under which specialists labor who leave their homes to attend a general scientific meeting where they will probably hear only a few papers on the particular subject in which they are interested. We therefore regard it as a high compliment to the Academy that after having contributed your communications to the program, we have received from you the moral support and encouragement of your presence during the whole period of the sessions. This is greatly appreciated by the members of our institution.

And now adjourning for the last time in the present century we will visit the Museum, and the microscopic exhibit in the Reading Room. Some of our members will join with the delegates from sister institutions tonight in welcoming the second century of the Academy's existence.

The rest of the afternoon was devoted to the examination of one hundred and thirty-two microscopes displayed in the Reading Room, and a selection from the Academy's superb collection of butterflies arranged on the gallery surrounding the New Hall.

THE BANQUET.

The actual anniversary of the birthday of the Academy was celebrated by a banquet in the evening, when one hundred and sixty delegates, members, and guests, assembled in the New Hall, which was beautifully decorated for the occasion. The tables were arranged in a long rectangle, the center of which was filled by a collection of palms, ferns, and flowering plants. The guests arranged themselves in friendly groups and the Chair was taken by the President, Dr. Dixon. On his right were placed the Hon. Rudolph Blankenburg, Mayor of Philadelphia; Hon. John Cadwalader, Vice-President of the Academy; Mons. Jean de Pulligny, Director of the Commission of French Engineers to the United States; Charles Custis Harrison, LL.D., late Provost of the University of Pennsylvania; William J. Holland, Sc.D., LL.D., Director of the Carnegie Museum, Pittsburgh; Edward J. Nolan, M.D., Recording Secretary and Librarian of the Academy; and Walter Horstmann. On the left were seated Edwin G. Conklin, Ph.D., Vice-President of the Academy and Professor of Biology in Princeton University; Henry Fairfield Osborn, LL.D., Sc.D., President of the American Museum of Natural History; J. Percy Moore, Ph.D., Corresponding Secretary of the Academy and Assistant Professor of Zoology in the University of Pennsylvania; Theodore N. Gill, A.M., M.D., LL.D., Professor of Zoology in George Washington University; Henry G. Bryant, LL.B., President of the Geographical Society of Philadelphia; and Edwin S. Dixon.

Dr. Conklin in his capacity as Toastmaster, remarked:

Gentlemen: We have come to the last and crowning event in this Centenary Celebration of The Academy of Natural Sciences of Philadelphia. Anniversaries mark something more than mere length of life—tombstones do that; anniversaries mark progress. They are milestones, rather than tombstones; and to-night we pass one great, one major milestone in the history of this institution.

It is not always easy to distinguish between milestones and tombstones. You know the story of the old lady, who, visiting friends in Cambridge, found a stone by the roadside inscribed "1 M. from Boston." Reading it with emotion "I'm from Boston" she remarked "how simple, how sufficient!"

But we are not now on the subject of tombstones. We are passing one of the milestones, as I have said—one of the major milestones.

The Academy of Natural Sciences of Philadelphia has many distinguishing characteristics. One of them is the fact that it was not founded by Benjamin Franklin; but I think it is more than probable that some good and ingenious, if not ingenuous, phylogenist might be able to trace certain of its splendid characteristics back to that great founder. At least, we may say that we are, in a way, related to the American Philosophical Society, our elder sister, which was the product of the fertile brain of the philosopher and statesman.

The title of this institution has always impressed me as being a particularly modest one: The Academy of Natural Sciences of Philadelphia. We have evidence here to-night, and have had throughout this whole celebration, of the fact that The Academy of Natural Sciences in Philadelphia is an Academy that

is known throughout the world. I was amused, a few years ago, to see in Switzerland the title of a certain hotel, *L'Hotel de l'Universe et de Genève.* The title of this Academy might, from this time forth, be, "The Academy of Natural Sciences of the World and of Philadelphia."

Some of you who have not been here very frequently have been amazed, I am sure, as I have been, at the transformation that has taken place. Those of you who met in the old library in the days not very far in the past will fail to identify that hall with this bower of blossoms. In truth the Academy has had a new birth within a few years past; or, speaking biologically, I might say that it has undergone a complete metamorphosis. It has passed from the tadpole stage into that of an imago. This metamorphosis has come about through the good management, wise foresight, skilful care, of one man, he who sits on my right, the Commissioner of Health of Pennsylvania, the President of the Academy, Dr. Samuel Gibson Dixon. That for which so many in the Academy have longed and labored has at last come. It came in the form of a good, substantial fireproof building. It is said of one of the Emperors of Rome that he found that city brick and left it marble. It can be said that Dr. Dixon found the Academy serpentine and left it reinforced concrete.

It is not my function, however, to make an address. My duty is a very minor one: I have merely to call on those who shall instruct and entertain you. I do not say that I am to "introduce" those who are to give this pleasure for I should not care to introduce those who are better known than myself. You may have heard the story of how President Stanley Hall, of Clark University, arrived on the evening train at a town, just before the hour at which he was to give a lecture, and was met at the station by one of the committee. He was taken in a carriage to the lecture hall, and at once went on the platform. The man who had brought him from the carriage walked to the front and said, "Ladies and Gentlemen: I have the great pleasure and honor of introducing to you to-night a man whose name is a household word, one who is known from the Atlantic to the Pacific and from the Canadian border to the Gulf of Mexico—a man whose name, as I have said, is a household word. I cannot think of the name at this moment, but he is the President of that very well-known university, a university that has been heard of all over the world, not merely in this country, but in Europe, an institution that everybody knows. It is so well known that I need not mention the name. The name of that university is —. Well, in truth, ladies and gentlemen, I do not know the name of the university; but, as a matter of fact, on the way from the station up here, I found that this gentleman was a very delightful fellow, and I introduce him."

Now it is that way frequently, I think, with introductions, so that I shall merely call on those who are to speak.

During the latter part of last week, I received a telegram from the President of the Academy. It was reported to me over the telephone from the telegraph office, and the message came to me that the President had appointed me Post-

master. That sounded pretty well, and I inquired at what place I had been appointed the Postmaster. I wanted to know that, and also what the salary was; and then I learned (I must confess, with a good deal of disappointment) that I was not a Postmaster after all, but only a Toastmaster. Some who agreed to speak have backed out. Still, there is plenty of talent here; and I am glad that we have with us to-night His Honor, Mayor Rudolph Blankenburg, of our goodly city of Philadelphia.

MAYOR BLANKENBURG:

Mr. President, Members of The Academy of Natural Sciences of Philadelphia, and Guests: I do not know what you have done that I should be inflicted upon you to-night. I came here confident that I would not be called upon to speak on this auspicious occasion. One of the prerogatives of the office of Mayor of Philadelphia is an invitation to every banquet that takes place; the penalty, almost invariably, that he must earn his "meal ticket" by a speech. If I only had the capacity, I could eat enough during the four years of my term to last me for the rest of my life should I live to be a hundred, but unfortunately, I have not that capacity.

A feeling of awe overcomes me when I look into the faces of learned and scientific men because they are so far beyond my ken that a sense of profound humility overcomes me in their presence. This sensation of insignificance has been materially dispelled this evening as I look at the magnificent dining room presided over by Dr. Dixon. We have before us beautiful decorations, and the elaborate menu which we have discussed, as well as everything else connected with it, including liquids, has convinced me that scientists are only mortals after all.

I know that you have enjoyed yourselves thoroughly. You have partaken of the good things set before you and some of you may even have indulged in something besides Schuylkill water; (I should have said, "some of *us.*")

I have made a discovery this evening—which is of such importance that it must be announced first before this august assembly. It is nothing less than that the forty women who are as much members of the Academy as any of you men, do not seem to be able to eat. This is the most remarkable discovery of recent years. I am sure these ladies would not be excluded from the feast had they learned to eat like men![6]

I shall be brief, as there are many speakers to follow me. We are proud of The Academy of Natural Sciences of Philadelphia. It is known all over the world and is one of the institutions that appeals to every citizen. The Academy has done much to give Philadelphia the name and the fame to which we are justly entitled as a center of learning. I believe the collections in your building are as extensive and as valuable as those in any similar institution in the United States. They have been gathered through the energy and care of the men who have, in one hundred years, from small and humble beginnings, succeeded in giving to Philadelphia its foremost scientific society. How it has flourished in

[6] In allusion to the fact that there were no ladies present.

recent years, and especially during the term of your office, President Dixon, is well known to all. A splendid future is in store for us of service to the City, the State and to the whole country, in collaboration with the many other educational institutions of a similar character of which we boast.

We should not duplicate too much, but try to have every institution attend to its own province and functions. Every institution of learning ought to have an individuality of its own, and I believe that the Academy has an individuality that is not part and parcel of any other institution of our city.

Philadelphia is going to build a new Free Library. This Library will be located on the Parkway. (Whenever I hear the Parkway mentioned, I feel like crawling into a hole and pulling the hole in after me.) There are many people in Philadelphia who think that the Parkway is the most important project before the public to-day. I am not of this opinion. We all favor the Parkway; we all want to beautify Philadelphia, make her something like Paris, at one time the most beautiful city of the world. As we know, Paris has the *Champs Elysées*. There is nothing quite equal to this Paris "parkway," as we would call it in our vernacular. We shall give Philadelphia a *Champs Elysées*, only let us be reasonable as to time. We have no Baron Haussman nor Emperor Napoleon, who simply demolished and built up as they pleased, because they were accountable to no one for their acts. If we had commenced operations forty years ago, Philadelphia to-day would probably be as beautiful as Paris, but we were utilitarians then and had little thought for the beautiful. Now we have awakened, and it is not yet too late.

We are going to finish the Parkway, and on this Parkway, almost opposite the Academy of Natural Sciences, we shall build a new Free Library. We mean to make this library one of the institutions of the country. I ask of you here present, as I request the gentlemen at the head of the Free Library, not to enter the domain of the other; that is, not to duplicate or to waste force in the same direction. Let each be original in its own way. What is the use of a library with books of reference that will be rarely used and then have these books duplicated across the street? You have a library with many rare scientific books that are useful to you in your own researches. There is no sense in having in a library across the street the same books. Let us cooperate. With cooperation we can have everything in Philadelphia that will tend towards the benefit and welfare of the whole community.

We are all proud of Philadelphia, even those who live at a distance, even those from Boston, the "Hub of the Universe." Philadelphia is one of the great and leading cities of the world. We have many institutions that are not to be found elsewhere. Take Girard College, with its vast grounds and fine buildings. Stephen Girard, a Frenchman, gave us Girard College; his name is honored and will be revered for all time. Fifteen hundred is the average number of orphan boys who are there educated year in and year out, free of charge. They are housed, fed, clothed, and educated, and many of the graduates of that college

are to-day citizens of prominence in our commonwealth and all over the United States. We have the finest public schools, we have the University of Pennsylvania and many other educational institutions, each in its own way adding its share toward the education of our people and the advancement of our great country.

One more thought—a thought that has been dear to me for many years: Science is one of the great powers for progress and light, but it must be combined in its teachings with hard, common sense. Let us get as close as we can to nature, for all science comes from and is closely related to nature, and the more natural we are, the wiser we shall become. Sense and science should govern us in the problem of government, especially that of municipal government, for it comes closest to us and is all-important in the destinies of our land. If we have honest, efficient and pure municipal government, the question of the future of our country will be solved.

We are to-day attempting in Philadelphia to solve this important question. Our people suffered for many years because selfishness had taken the place of public spirit; avarice, that of high-minded devotion to the public good; cowardice, that of courage; partisanship had conquered patriotism. The people had for many years failed to rule Philadelphia, just as they failed in other municipalities. At last we proclaimed in our own city a new Declaration of Independence. The people arose in their might, threw off the shackles, declared for and obtained freedom. This is a government, as Lincoln so vividly and tersely expressed it, "of the people, by the people, and for the people." Let us have this kind of government. It is the legitimate rule; the natural, the scientific and philosophical direction of public affairs. You members of the Academy of Natural Sciences can help to establish a "Public Academy of all the Sciences," of splendid common sense and patriotic spirit for the whole city. Then we shall solve the great question of municipal government, of honest and progressive government on business lines.

Forgive me for speaking of myself, but thirty, aye forty years of my life have been devoted to this problem. The opportunity has at last presented itself for solution. We have commenced and are doing the best we know how. We are applying scientific methods to every department of the city government, and I ask you, members of the Academy of Natural Sciences, to help us apply the principles that prompt your devotion and energy, to the solution of the question of municipal government. Then one hundred years hence, at your bi-centennial celebration, it will be related as a proud historical fact that, when the Centenary of the Academy was celebrated, the prediction was made and has been fulfilled that this great society could, would and did lend its weighty influence to the popular cause. That it applied the same thoughts and ideas to the solution of municipal government that it has given to the investigation and expansion of the natural sciences.

Then the second centenary of this influential body will not only be identified

with the accomplishment of the noble purposes that you and all of us have set out to accomplish, but it will also behold and celebrate the solution of the great municipal problem which involves the permanent existence of the government that was established by Washington and preserved by Lincoln.

Our government is founded and will be perpetuated on thoughts and ideals expressed in four of the most illustrious documents ever emanating from human mind—the Declaration of Independence, the Constitution, Washington's Farewell Address, and Lincoln's address at Gettysburg. Give us the government defined by these patriots and this country will be a beacon light to all nations for all time to come.

DR. CONKLIN:

Many different countries are represented here to-night. One of them has been foremost in the natural sciences, the land of Cuvier, the land of Saint Hilaire, the land of Lamarck. I have great pleasure in presenting to you Mons. Jean de Pulligny, the Director of the French Commission of Engineers to the United States, who will convey the greetings of the French scientific societies on this occasion.

MONS. DE PULLIGNY:

Mr. President and Gentlemen: It is an agreeable duty and a great honor to me to address a meeting of such men as are gathered around me this evening. I have come here to carry the greetings of all French scientific societies, and especially the *École Polytechnique*, of which I had the honor of being a pupil in my youth, a good many years ago.

If you can look back with legitimate pride on a century of useful work, the *École Polytechnique* can claim sixteen years more of kindred occupation.

I regret that we will not meet at the end of another century to comment on the success of the Academy during the intervening years. So, gentlemen, I renew the hearty congratulations of the French societies, especially the *École Polytechnique* to which I shall carry back the greetings of The Academy of Natural Sciences of Philadelphia.

DR. CONKLIN:

We have with us the distinguished President of a sister institution, believed in New York, and perhaps elsewhere, to be the greatest museum of natural history in the world. I imagine that on this occasion it would scarcely be safe to insist on this; but there were some German scholars over here studying museums, a few years ago, and one of them went back and published a report in German, which said that the plans of the American Museum of Natural History of New York would, when carried out, give it that rank. We are, therefore, particularly pleased to have with us the President of that institution, one who is no stranger in this place; who was associated intimately with Cope, who called him "one of my boys." He is the man who, in the Bronx

Zoological Garden, has brought to our doors the wonders of the living world; and who, in the American Museum of Natural History in the Central Park, has made to live again the strange monsters of a past world. I have pleasure in calling upon Professor Henry Fairfield Osborn to speak to us upon the cultivation by the Academy of the science of paleontology.

DR. OSBORN:

In addressing the Mayor of Philadelphia, the President and members of The Academy of Natural Sciences of Philadelphia, and the Toastmaster, I rise with the greatest pleasure to the toast of "The Academy of Natural Sciences of Philadelphia and its Relation to the Development of Paleontology in America."

I bring greetings to the Academy from the scientific institutions of New York City, the American Museum of Natural History, and Columbia University, as well as an expression of the debt that all of us constantly feel to the men who have worked within these walls and have developed that division of the biology of the past known as paleontology.

This country has ever afforded peculiar opportunities for the development of this branch of science which was founded in France by the genius of Cuvier. There were first the Pleistocene fossils discovered in the Eastern and Middle States, some of which Thomas Jefferson considered of greater interest than the political developments in the stirring period of 1808. Then came our Western Territory, an arid region constituting an unknown continent. The first explorers of the *Mauvaises Terres* brought back a revelation of the existence of wonderful records of the world's life. Fortunately for science as early as 1851 these fragments were brought to Philadelphia, and to the hands of one who lives immortal in the history of American science and the world's science, Dr. Joseph Leidy.

Never was there a greater opportunity and never was there a man more ready to grasp it than that quiet, unpretentious, unassuming, wonderfully gifted observer of nature. It is particularly interesting to review his work, which was written in the exact spirit of Cuvier, and to see his long record of direct observation of the entire extinct fauna, not only of the East but especially of the great western territories,—to find how permanent that work is, how well it stands the test of time, how accurate his descriptions, how perfect his figures and illustrations, and how, even today, they form the best standards for all the work which has been done since. So I think it may fairly and truly be said, without any exaggeration incidental to this historic moment, that Joseph Leidy was the founder of the paleontology of the vertebrates in America. After a continuous series of epoch-making papers and contributions which he was in the habit of contributing year after year to meeting after meeting—he brought his work to a climax in 1869 when he published his great monograph, *The Extinct Mammalian Fauna of Nebraska and Dakota,* in the JOURNAL of the Academy. That work still ranks in its breadth and its accuracy as one of the finest contributions that has been made to vertebrate paleontology in this country. In fact, Leidy started

with an entirely new world of life, because he soon learned that he could not base his study of American fossils on the work of the French paleontologists, for the life of our western regions was not known in the Old World, every specimen represented a new species, a new genus, or a new family, and in some cases a new order.

It proved an unfortunate circumstance for Leidy that paleontology is a science requiring ample expenditure of money, for as years went on he was reluctantly obliged to leave the field to his equally ambitious and more wealthy pupils and followers, Cope and Marsh, whose writings belong to the new, or Darwinian period of the science, while Leidy was essentially pre-Darwinian. The three men, were, however, intimately associated with the Academy; they put the science of vertebrate paleontology as coming from the United States on a new basis, commanding the attention and admiration of the savants of the Old World. This was a great achievement, and its beginnings issued from these halls.

It is most interesting to contrast the characters of the three men, Joseph Leidy, Edward Drinker Cope, and Othneil Charles Marsh. They were as different as any three men could possibly be made by nature and nurture. In the admirable speech of your Mayor nothing truer was said than that he had made a discovery at this dinner, namely, that scientists are only mortals, after all. Whereas Leidy was essentially a man of peace, Cope was what might be called a "militant" paleontologist; whereas Leidy's motto was "Peace at any price," Cope's was "War, whatever it costs." Perhaps there was a scientific Providence in all this, perhaps these antagonistic spirits were necessary to enliven and disseminate interest in this branch of science throughout the country. This subtle combative quality in paleontology seems a strange quality; by a strange inversion, the more ancient, the more difficult to study, the more refractory the fossil, the greater the animation of discussion regarding its relationship and descent. From this subtle ferment there arose the famous rivalry which existed, not between Leidy and either of the others, because it was impossible to quarrel with Leidy, but between the descendant of a Quaker family and the nephew of a great philanthropist. It is certain that when I took up the subject as a young man and first came to the City of Brotherly Love thirty-five years ago, from the quiet shades of Princeton, I always expected to learn of some fresh discussion, some recent combat; and it was always here in the Academy of Natural Sciences that one could find one of the centers of the convulsive movements. I remember one day coming into this very hall and finding two of the youthful attendants carrying on an animated discussion regarding a dispute that they had overheard at the meeting of the Academy the night before.

Whereas in Leidy we had a man of the temper of an exact observer, Cope was a man who loved speculation; if Leidy was the natural successor of Cuvier, Cope was the follower of Lamarck, a man of remarkable inventive genius. Leidy covered in his contributions to the Academy the whole world of nature from the Protozoa and Infusoria up to Man, and lived as the last great naturalist of the

old type who was able by capacity and training to cover the whole field of nature, whereas Cope mastered, in itself a wonderful achievement, the entire domain of the vertebrates from the fishes up. Marsh, with less breadth and less ability, nevertheless was a comparative anatomist of a high order, and had a genius for appreciating what might be called the most important thing in science. He always knew where to explore, where to seek the transition stages, and he never lost the opportunity to point out at the earliest possible moment the most significant fact to be discovered and disseminated.

These three men, therefore, approached the subject from the standpoint of three entirely different temperaments and their contributions were of an entirely different character. Leidy was a great describer, Cope was a phenomenal taxonomist, while Marsh was less productive than either but extremely effective in everything he published. Leidy was not a taxonomist or classifier of animals, he was a great naturalist; Cope revolutionized every class of vertebrates which he treated: fishes, amphibians, reptiles, mammals, by his novel arrangement of their systematic characters and his daring innovations in classification.

I had the pleasure of knowing Leidy slightly and of a long personal acquaintance with Marsh; I knew Cope very intimately,—I was, as your toastmaster said, "one of his boys." He always welcomed Scott and myself to his house; his library and his collections were as open as those of a museum. On one memorable occasion when I visited his house he pulled out a drawer of his black walnut work-table, where he always sat and wrote his papers, and brought out a packet carefully done up in paper and twine, saying, "Osborn, here are some records that you have never seen before." I said, "Well, what are they?" He replied, "These are my Marshiana, here is everything relating to the mistakes which that man Marsh has made; and when the time comes, Osborn, I am going to launch this on the world." Well, he did; the bombshell was exploded in due time, and this great mass of information regarding the supposed incapacity of Marsh was spread on the pages of the *New York Herald* in one of its Sunday issues. The very next Sunday, however, Marsh, who, it appears, had likewise been accumulating a private stock of Copeiana, proved with equal success that Cope's life was one long string of errors from first to last.

Heredity makes strange bedfellows. It is only by the most extraordinary combination of personal characteristics that we find among scientific men of the greatest capacity, such strange mixtures of personal qualities side by side with genius.

Time, however, softens things and also brings about some strange recombinations and associations. Marsh in the course of time passed away, Cope followed him, and Mrs. Cope was good enough to send to the American Museum of Natural History his historic black walnut work-table together with a complete set of his writings. I remembered the drawer out of which Cope had pulled his "Marshiana." Shortly afterward Director Walcott invited me to succeed Marsh as paleontologist of the United States Geological Survey, and soon

after I received from New Haven all of Marsh's manuscripts; that is, everything not published which related to his unfinished monographs. Where was the best place to put these manuscripts? Why, in the same drawer in which Cope had collected his Marshiana, and there they may be found today.

Well, gentlemen, let me in closing wish the Academy of Natural Sciences the company and association of many more such men as Leidy, Cope, and Marsh; let me express the hope that this present life of the Academy with its new opportunities, may be a continuation of the old life, but that with improved conditions there may come the discovery among the young students of the public schools and your University, men of genius to succeed those we are honoring tonight.

If you have in this great city, as is undoubtedly the case, young men with a talent for such studies, here is where they will find their opportunity, here is where they will be welcomed, and here is where the Academy will develop the men who will continue its glorious traditions.

THE PRESIDENT:

I had declined to speak this evening because I thought it my place to listen to what others had to say about the institution that has been so effectively sustained by the citizens of Philadelphia and of the Commonwealth of Pennsylvania, but after listening to the history of the wars between the naturalists of the past, at this time when the Academy has just received the most gracious testimonials from her sister institutions all over the world assuring us of their sympathy and cooperation in our work, one is encouraged to hope for an international code of peace. I realize more fully than ever that scientific and educational institutions are effective agents in establishing such a code. Most gratifying to our members and to the citizens of Philadelphia in general are the compliments paid the Academy by scientists from every part of the world and such assurances of cooperation give rise to reasonable hope that the work of the Academy and kindred institutions will be an important factor in the establishment of peace on earth and good will among men.

DR. CONKLIN:

We are greatly honored to-night in having with us the Nestor of American Zoology, a man who was contemporary with Joseph Leidy, and the other men of whom we have just been hearing. I refer to Dr. Theodore N. Gill, of the National Museum at Washington. Here at the Academy we have the custom of dating events as before or after Nolan. Dr. Gill tells me that he was elected a member of this Academy in the year 1860. Now, since Dr. Nolan became connected with the Academy as a boy in 1862, we have to admit that Dr. Gill belongs to the pre-Nolan period. Dr. Gill has recently been very ill, and he has paid us the great compliment of coming here and staying throughout the whole celebration; and I am now glad to call on him to tell us whatever he may please, just as his spirit may move him.

As this is the seventy-fifth birthday of Dr. Gill I propose that we stand and drink his health.

This was cordially done.

DR. GILL:

It is fifty-two years since I was elected a Correspondent of this Academy. When Dr. Nolan gave his address, night before last, it was with the greatest pleasure that I listened to his reminiscences. When admitted to association I was given all the privileges of the society: I had a pass-key, and could visit the Academy not only by day, but also by night. I take the greatest pleasure in acknowledging the advantages enjoyed by me at that time, and to testify as to how greatly I enjoyed the benefits conferred by the institution and how persistently I attempted to derive from it all the benefits possible.

The Academy was then a comparatively small institution, but nevertheless far ahead of any other of the kind in the country. In that early time (that is, during the last of the 50's and the first of the 60's), there were in Philadelphia quite a remarkable collection of young students of about the same age, almost all of whom belonged to the Academy. One of these that I recall (and I think that I recall almost all of them) was Edward Cope. Another was Horatio Wood, who is the only one of the lot now living.

Cope, as you know, was versatile. At that time, he was almost exclusively interested in the reptiles, but he developed year after year, in many ways, so that he covered all nature, not even confining himself to the vertebrates.

Horatio Wood was at that time more especially interested in the myriapods and the horny corals.

George Horn was also active. He was at that time also interested in the corals. A short time after he took up the study of Coleoptera, in which he became a past master.

Gabb was actively engaged in the study of invertebrate paleontology.

These men occasionally assembled together. One such meeting was in March, 1861, when William Stimpson was present. Absenting himself for a time he came back with some doggerel, in which he included those present. It was dedicated to the "Polymythian Society of Monosyllabics, who contributed nine-tenths of the Proceedings of the Academy of Natural Sciences in 1861," and as nearly as I remember it ran somewhat as follows:

"Into this well of learning dipped,
With spoon of *Wood* or *Horn* —
For students, *Meek* and lowly,
Silver spoons should treat with scorn.
Though *Gabb* should have the gifts of *Gill*,
As *Gill* has gift of *Gabb*,
'Twould show a want of judgment still,
To try to *Cope* with *Meek*."

The Academy was a most delightful place. I made frequent visits from Washington, and in 1861 I held a Jessup Fund Scholarship for three months, enjoying largely my continued stay in Philadelphia. During that time, I had the free use of the building, and still had a pass-key, which I freely used.

Among the older members who impressed me were Leidy, Conrad, Isaac Lea,

and Tryon. Leidy was a handsome man of striking personality but somewhat round-shouldered. He was a man of the widest range of knowledge and information and was able to put his hand almost immediately on any book of reference. He was familiar with all forms of life from Amœba to Man. I entered the University as a medical student under him. As a lecturer, he was not eloquent, but he gave the facts in a trenchant, impressive way which arrested the attention and gave direction to the thoughts of the student. In range of knowledge, he excelled anyone that I have ever known—even Cope was much inferior in that respect, but Leidy was not a generalizer and did not care to consider questions from a philosophical point of view. Cope, on the contrary, was willing to discuss any philosophical question. One of the subjects of the day (that was before Darwin's day, you know) in which Cope was deeply interested was the vertebrate theory of the skull. That has been so completely buried that I fear many of you may not be familiar with what the theory was. It held that the skull was composed of four vertebræ. It was more especially advocated by Richard Owen, and widely accepted in England. The first discussion of any length I had with Cope was on the subject of this vertebrate theory. He strenuously advocated it; I contended against it, and gave my reasons. We went to Leidy and appealed to him, and he said: "I do not take any interest in these questions. I do not believe in the theory."

DR. CONKLIN:

Gentlemen: We have with us the director of another museum, one of the greatest of this country, that of the Carnegie Institute of Pittsburgh. Wherever you go, in the great museums in this country or abroad, you will see life sized models of that prehistoric beast, *Diplodocus carnegii*, a creature which always reminds me of the poet's description of the comet: "Ten thousand miles of flaming head; ten million miles of tail."

I call upon Dr. William J. Holland, of Pittsburgh.

DR. HOLLAND:

Through the kindness of the Toastmaster I have been spared the agony of suspense, which sometimes afflicts those who are called upon to make after-dinner speeches. You may have heard that Daniel accounted for his escape from the lions by stating that they were to make an after-dinner speech and had therefore lost their appetites. I have dined in peace and face you with a glad heart and unimpaired digestion.

When I was a boy of ten my mother brought me to Philadelphia. I had in my pocket four gold dollars—little gold dollars—some of you remember them. I went to the bookstore of J. B. Lippincott, and I bought Dr. Livingstone's first volume. I have that book in my library to-day. It is the first book bought with my own money, and stands first in a long list of thousands of volumes which are in my library. It is on that account one of my treasures. My mother was

wont to tease me afterwards because I used to express fear that Dr. Livingstone would discover everything in Africa before I could have a chance. The day after visiting Lippincott's bookstore I visited the Academy of Natural Sciences, lodged in that tall narrow building, which has been referred to this evening as having stood where later stood the Hotel Lafayette. There I feasted my eyes upon Dr. Kane's polar bear. For years the memory of that wonderful sight has lived with me, and whenever thinking of the arctic regions, Dr. Kane's polar bear, by the laws of natural association, has come back in memory, glorified, as are all the visions of childhood. Yesterday, after more than half a century, I saw Dr. Kane's polar bear again. Horrible! How the now time-worn relic has shattered the memories of childhood! Taxidermy has made great advances during the past half of a century. We can do better in the way of stuffing polar bears to-day. We had three polar bears sent in cold storage to us from within the Arctic Circle only a short time ago, and prepared them in Pittsburgh. Had anybody told me more than fifty years ago, as I stood looking at Dr. Kane's bear, that I should myself have three bears of the same species shipped to me from Siberia to Pittsburgh, and that I should have them skinned there and mounted for a museum, I should have declared the idea supremely ridiculous. But the thing has actually happened.

To be a member of The Academy of Natural Sciences of Philadelphia seemed to me in my youth the highest honor which could come to mortal man; and later, when good old Doctor Ruschenberger, Mr. John Jordan, the President of the Historical Society of Pennsylvania, and Dr. Nolan proposed me for membership, I was one of the happiest young men in America.

The memories which cluster around this institution are precious to me. I will not speak of those who are living. I knew Durand and Fiot, and many other botanists, who in my youth were connecting links with the early days of this institution. When Mr. Stone entertained us this afternoon with his most interesting account of the pine-barrens of New Jersey, there came back to me a flood of recollections of certain golden days which I passed in company with Durand, Fiot, my own father (who was a botanist), and my mother's cousin, Francis Wolle, on the occasion of an excursion to New Jersey to study and collect plants. I am glad to recognize here to-night the son-in-law of Francis Wolle, Professor Doolittle, the honored professor of astronomy in the University of Pennsylvania. These halcyon days, when all the world was young, and my friends were the wisest of all men, when the flowers we gathered were the brightest, and the bird-songs we heard were the sweetest, will never come again.

It has been my lot for a number of years to preside over the destinies of the great museum established by the generosity of one of the most noted sons (by adoption) of Pennsylvania at the headwaters of the Ohio. Supported by the generous gifts and sympathetic counsels of Andrew Carnegie we have undertaken to do in the western part of this great Commonwealth work allied to that which

your Academy is doing here on the banks of the Delaware. The kindling inspiration, the fire on our altar, came from the hearthstone of science here. There is a great field for research before us, as we stand in the gateway of the West, through which Long, and Lewis and Carke, went forth for their journeys of exploration, but the original impulse and the exemplification of what is to be done have come to us through such men as your own Say, Audubon, LeConte, and Leidy.

But let us forget Pittsburgh for a moment and come back to this institution. Gentlemen, the best library of scientific literature in the departments of zoology and botany in North America is found under this roof We owe a debt to Thomas B. Wilson and the men who have come after him for having assembled here in this library the works of the great scientific investigators in these fields, as they have from time to time appeared. We are attempting in Pittsburgh to build up such a library; but, only the other day, when one of my associates proposed to me to prepare a bibliography of the ichthyology of South America, I was compelled to say to him, "Run over to Philadelphia to the Academy of Natural Sciences and there prepare the manuscript in the form in which it ought to be. It is idle to cite titles at second-hand. The books are in Philadelphia. Go there." He went, and we have secured a bibliography covering the subject, as I trust, in a satisfactory manner. In order to do it we had to send to Philadelphia.

Gentlemen, science, which is simply ordered knowledge, has had no more efficient handmaiden in this country during the last century than The Academy of Natural Sciences of Philadelphia, the Centenary of which we are celebrating at this time. I am a member of many of the great societies in Europe, but, as I said a few moments ago in conversation with my friend Dr. Nolan, the Zoölogical and Linnean Societies of London, the *Société Zoologique de France,* and a score of others, which I might name, have none of them done more useful work, nor accomplished better things for the advancement of human knowledge, than this Academy, so admirably presided over to-day by our honored friend, Dr. Dixon.

As Americans and as Pennsylvanians we are proud of The Academy of Natural Sciences of Philadelphia, we rejoice in the achievements of the one hundred years which have passed, and our wish and hope is that, when another hundred years shall have rolled their course, this institution will stand proudly, wearing even greater honors, and possessed of even more exalted reputation, than now belong to her.

DR. CONKLIN:

Gentlemen: We are celebrating to-night not merely the Centenary of The Academy of Natural Sciences of Philadelphia, but also the Semi-Centenary of Dr. Edward J. Nolan's connection with this Academy. Let us stand and drink to the health of Dr. Nolan.

I call upon Dr. Nolan "to read the 'rough minutes' of the meeting."

DR. NOLAN:

Gentlemen: I can say metaphorically as well as literally that I am not yet too full for utterance, but I am reminded of a friend who has undergone so many surgical operations that she declares she has nothing left but lungs and recollections. I have, however, in addition, a tongue, and as long as the lungs continue to supply the motor force, I am willing to talk in the interest of the Academy.

I have been dealing earlier in the proceedings somewhat extensively in "recollections" but were I not surrounded by friends, I should feel tonight as a stranger in a strange land. The Academy moved into this building in 1876, when I had for fourteen years been administering the affairs of the Library and the Publication Office to the best of my ability and with little or no assistance. Many of you remember the aspect of this old hall, austere, not to say dingy, in which the work was continued until the completion of the stack building, and we are startlingly conscious tonight of how it has been transformed by the energy of the President. In the northeast corner was the little room in which I sat and worked for more than thirty-six years. Its only attraction was the view it afforded of the beautiful trees in Logan Square. Directly to the west, separated by an alcove, was the even darker and gloomier room inhabited by my beloved preceptor, Joseph Leidy, of whom you have heard so much tonight. There he did much of the work which has rendered this society illustrious, always ready, no matter what his engrossment, to give his time for the assistance of others. Arranged around the hall were equally small and gloomy study rooms, every one teeming with recollections of men who have been efficient in promoting the credit of the Academy. These were placed, as far as possible, at the service of visiting naturalists as well as resident students, and in one of them the genial Elliott Coues from time to time did much work in ornithological bibliography. He told me on one occasion that it was the most satisfactory room in which he had ever worked "for if I had a good fishing-pole I could draw to my table every book I need without getting up." A little beyond, Heilprin, for a time, discharged the duties of Executive Curator, and the last room on the north side was for some months inhabited by the venerable Titian R. Peale, a contemporary of the founders.

Recollections become more vivid as I go on, regardless of the lovely lights and plants and draperies and evidences of good cheer that everywhere delight our senses tonight. There to the right of where I now stand Tryon was ensconsed for years, engaged on his epoch-making work in conchology, and just beyond Henry C. McCook elaborated the results of his fine field-work among the ants and spiders. The other rooms were occupied from time to time by equally illustrious men. It was to the door directly opposite mine that the good angel of a distinguished arctic explorer directed his steps when he succeeded in enlisting the Corresponding Secretary's interest in his plans. Had he turned to the right instead of to the left he would have met with but scant encouragement.

I have a vivid remembrance of another social gathering in this hall. It was a very generous dinner given by the lamented William S. Vaux to the Centennial Commissioners in 1876. The affair was a distinguished success, the provision both of solids and liquids being generous and the spirit of the gathering most genial, but when I contrast the surroundings of that occasion with those we are enjoying tonight, I am impressed with the fact that "the world do move."

The only other event of the kind in the history of the Academy is a pleasant tradition, and not one of my recollections. It was a dinner given in 1854, at the instance of Dr. Ruschenberger, who acted as Chairman, in Musical Fund Hall. One hundred and four members enjoyed the feast and joy was unrestrained. At the risk of causing discontent with the elegant and sufficient bill of fare provided for this evening's entertainment, I shall, as an illustration of the change in social usage, call your attention to the perfectly exuberant catalogue of eatables provided on that occasion. Without dwelling too much on details I may say that while there was but one soup, and that nameless, there were two kinds of fish, four boiled meats, ten side dishes, the French names of which I shall not pronounce out of regard for the feelings of Mons. de Pulligny. Then there were five roasts: beef, capons, saddle of mutton, turkey, and ham. Under game were served pheasants, prairie grouse, partridges, terrapin, and (it is to be hoped not too game) *fried oysters*. There were six entries under "Pastry"; ten under "Dessert," and the whole was washed down with Madeira, Champagne (Heidsieck and Mumm's), Pale Sherry, Claret, Brown Sherry, Scharzberg, Steinberg, Liebfraumilch, Brandy, Coffee, Whisky and, last but probably not least—Punch. Curiously enough there is no mention of ice cream, so apparently indispensable at the close of our contemporary feasts.

Strange to say the work of the Academy went on as usual, no notable additions to the death list having been recorded on the minutes of subsequent meetings.

I think our admirable committee on entertainment, while they no doubt have done as well as they could, have supplied no such provision for the inner man as is set forth on that bill of fare of 1854.

Of course, congratulations are in order. The President has indicated our feelings on that subject, and it is not necessary to say more. It is very likely, almost certain, so far as we know at present, that nobody here now will participate in the second hundred years' celebration of the Academy's birthday; but we do not know what may eventuate in this era of progress in biological science, and Metchnikoff or some one else may discover a life-renewing bacillus that will leave at our discretion the extent of our lives. If this be so, one reason for wishing to prolong our existence would be the anticipated joy of participating in the celebration of the Two-Hundredth Anniversary of the Academy; and if I meet with any of you on that occasion I am sure we shall be a bunch of jolly old boys. And so — Good Night.

DR. CONKLIN:

Now, gentlemen, we have come to the close of the first century of the Academy. Some of you may think we have got further but we are only entering upon the second century, and I propose that we all rise and drink to the continued growth and glory of The Academy of Natural Sciences of Philadelphia.

The toast was drunk standing and with the singing of *Auld Lang Syne* the company adjourned at 11.45 P. M.

DELEGATES TO THE CENTENARY CELEBRATION.

The following delegates were appointed by the institutions in connection with which they are named:

FRANK DAWSON ADAMS, Ph.D., F.R.S.,
The Geological Society of London.

JOHN W. ADAMS, V.P.M.
The University of Minnesota.

HERMAN V. AMES, A.M., Ph.D.,
Amherst College.

EDWIN S. BALCH, A.B.,
The Franklin Institute.

GEORGE A. BARTON, Ph.D.,
The Archæological Institute of America.

JOHN BIRKENBINE,
The American Institute of Mining Engineers.

JAMES ARNOLD BLAISDELL,
Pomona College, Claremont, Cal.

WALTER M. BOEHM, Ph.D.,
The State University of Iowa.

W. E. BRITTON, Ph.D.,
The Entomological Society of America.

ERNEST WILLIAM BROWN, A.M., Sc.D.,
The University of Cambridge, England,
The Royal Society of London.

HENRY G. BRYANT, LL.B.,
The Geographical Society of Philadelphia,
The Royal Geographical Society of London.

HIS EXCELLENCY HON. HELMAR BRYN, Envoy Extraordinary and Minister Plenipotentiary of Norway to the United States of America.
Kongelige Frederika Universitet, Kristiania.

THOMAS J. BURRILL, Ph.D., LL.D.,
The University of Illinois.

GARY N. CALKINS, Ph.D.,
Société Zoologique de France.

PHILIP P. CALVERT, Ph.D.,
Sociedad Aragonesa de Ciencias Naturales.

WILLIAM CAMPBELL, A.M., D.Sc., Ph.D.,
The University of Durham Philosophical Society, Newcastle-upon-Tyne.

E. P. Cathcart,
The University of Glasgow.
George Hubbard Clapp, Ph.B.
The Carnegie Institute and Museum.
The University of Pittsburgh.
William Bullock Clark, Ph.D., LL.D.,
Johns Hopkins University,
The National Academy of Sciences.
Richard A. Cleeman, M.D.,
The College of Physicians of Philadelphia.
F. V. Colville,
The Washington Academy of Sciences.
John H. Comstock,
The Entomological Society of London.
Melville T. Cook, Ph.D.,
The Connecticut Experimental Station,
The American Phytopathological Society.
W. M. C. Coplin, M.D.,
The Philadelphia Pathological Society.
Ezra T. Cresson,
The American Entomological Society.
Whitman Cross, Ph.D.,
The Geological Society of London.
Charles B. Davenport, A.M., M.D.,
Société Zoologique de France.
William Morris Davis, Ph.D.,
The Geological Association of London.
William T. Davis,
The Staten Island Association of Arts and Sciences.
Alvin Davison, Ph.D.,
Lafayette College.
Edward V. D'Invilliers,
The American Institute of Mining Engineers.
Raymond L. Ditmars,
The New York Zoological Society.
Hon. Samuel G. Dixon, M.D., LL.D.,
Accademia della Scienze Fisiche e Matematiche di Napoli,
Ateneo Veneto,
R. Scuola Superiore di Agricultura in Portici,
Accademia Gioenia di Scienze Naturali in Catania,
Società di Lettere e Conversazione Scientifiche, Genova,
I. R. Accademia di Scienze, Lettere ed Arti degli Agiati, Rovereto,
Università di Torino.

JAMES MAPES DODGE,
The Engineers' Society of Western Pennsylvania.
HENRY H. DONALDSON, Ph.D., Sc.D.,
The American Philosophical Society,
The University of Chicago.
CHARLES L. DOOLITTLE, Sc.D.,
The University of Michigan.
HENRY STURGIS DRINKER, E.M., LL.D.,
Lehigh University.
JONATHAN DWIGHT, JR., M.D.,
The American Ornithologists' Union,
The Linnæan Society of New York.
HON. W. A. F. EKENGREN, Chargé d'Affaires, Swedish Legation, Washington, D. C.
K. Vetenskaps Akademien,
Sällskapet for Anthropologi och Geographi.
DAVID G. FAIRCHILD,
The Bureau of Plant Industry.
WILLIAM GIBSON FARLOW, M.D., LL.D.,
The Linnean Society of London.
JOSEPH HORACE FAULL, Ph.D.,
The Canadian Institute.
EPHRAIM P. FELT, Sc.D.,
The Entomological Society of America.
CHARLES H. FERNALD, Ph.D.,
The Entomological Society of London.
J. WALTER FEWKES, A.M., Ph.D.,
The American Anthropological Association.
STEPHEN A. FORBES, Ph.D.,
The Illinois State Laboratory of Natural History.
HOWARD B. FRENCH,
Philadelphia College of Pharmacy.
CHARLES STUART GAGER, Ph.D.,
Torrey Botanical Club,
The University of Missouri.
THEODORE N. GILL, M.D., LL.D., Ph.D.,
The Smithsonian Institution.
CLARENCE McC. GORDON, A.M., Ph.D.,
Lafayette College.
SIR JAMES GRANT, M.D.,
The Royal Society of Canada.
MILTON J. GREENMAN, M.D.,
The Wistar Institute of Anatomy.

ROSS G. HARRISON, A.M., Ph.D.,
The American Association of Anatomists.
SAMUEL HENSHAW, A.M.,
The Museum of Comparative Zoology,
Harvard University.
REV. WILLIAM J. HIGGINS, S. T. L.,
The Catholic University of America.
FREDERICK W. HODGE,
The Bureau of American Ethnology.
JAMES W. HOLLAND, A.M., M.D.,
Jefferson Medical College.
WILLIAM J. HOLLAND, Ph.D., Sc.D., LL.D.,
The Carnegie Museum,
The Carnegie Institute,
The Entomological Society of London,
The Entomological Society of Western Pennsylvania,
The University of Pittsburgh.
EDMUND OTIS HOVEY, Ph.D.,
The New York Academy of Sciences.
LELAND O. HOWARD, Ph.D.,
The American Association for the Advancement of Science,
The Entomological Society of America,
The American Association of Economic Entomologists,
Société Entomologique de France.
MARSHALL AVERY HOWE, Ph.D.,
The New York Botanic Garden.
W. H. HOWELL, M.D., LL.D.,
The American Physiological Society.
GEORGE S. HUMPHREY,
Staten Island Association of Arts and Sciences.
HERBERT S. JENNINGS, A.M., Ph.D., LL.D.,
The American Society of Naturalists.
CHARLES W. JOHNSON,
The Boston Society of Natural History.
EMORY R. JOHNSON, M.L., Ph.D.,
The University of Wisconsin.
JAMES FURMAN KEMP, Sc.D.,
Columbia University,
Sociedad Cientifica Antonio Alzate.
WILLIAM A. LATHROP,
The American Institute of Mining Engineers.
FREDERICK S. LEE, A.M., Ph.D.,
The American Physiological Society.

F. L. LEWTON,
The Botanical Society of Washington.
WILLIAM LIBBEY, A.M., Sc.D.,
The American Geographical Society.
WALDEMAR LINDGREN, M.D.,
The Geological Society of Washington.
WILLIAM A. LOCY, Sc.D.,
Northwestern University.
JACQUES LOEB, M.D., Sc.D., Ph.D.,
The University of California,
Rockefeller Institute for Medical Research.
BRITA LONG,
Philadelphia High School for Girls.
FREDERIC A. LUCAS, Sc.D.,
The American Museum of Natural History.
SAMUEL BLACK MCCORMICK, LL.D.,
The University of Pittsburgh.
GEORGE G. MACCURDY, A.M., Ph.D.,
École d'Anthropologie de Paris.
American Anthropological Association.
JOHN M. MACFARLANE, Sc.D.,
The Royal Society of Edinburgh,
The Botanical Society of America.
R. TAIT MCKENZIE, M.D.,
McGill University.
CHEVALIER J. C. MAJONI, Royal Consul of Italy at Philadelphia,
Società Geografica Italiana,
Reale Istituto Lombardo di Scienze e Lettere.
JOHN W. MALLET, LL.D., M.D., Ph.D.,
The University of Virginia,
The Chemical Society of London.
SAMUEL J. MELTZER, M.D., LL.D.,
The American Physiological Society.
JOHN ANTHONY MILLER, A.M., Ph.D.,
Swarthmore College.
CHARLES SEDGWICK MINOT, Sc.D., LL.D.,
The American Association for the Advancement of Science,
The University of Oxford,
Reale Accademia della Scienze di Torino.
S. WEIR MITCHELL, M.D., LL.D.,
The College of Physicians of Philadelphia.
JOHN R. MOHLER, V.M.D.,
The Bureau of Animal Industries.

THOMAS H. MONTGOMERY, JR., Ph.D.,
The University of Texas,
The Texas Academy of Sciences,
The Marine Biological Laboratory, Wood's Hole.

THOMAS L. MONTGOMERY,
The Wyoming Historical and Geological Society of Wilkes-Barre.

GEORGE T. MOORE, Ph.D.,
The St. Louis Academy of Sciences,
The Missouri Botanical Garden.

H. F. MOORE, Ph.D.,
The United States Bureau of Fisheries.

J. PERCY MOORE, Ph.D.,
Société Zoologique de France.

EDWARD L. NICHOLS, Ph.D., LL.D.,
Cornell University.

REV. JULIUS A. NIEUWLAND, C.S.C., Ph.D., Sc.D.,
The University of Notre Dame.

C. EDGAR OGDEN,
The Delaware County Institute of Science.

HENRY FAIRFIELD OSBORN, Sc.D., LL.D.,
The American Philosophical Society.

SAMUEL C. PALMER,
Leland Stanford Junior University.

F. PAYNE,
University of Indiana.

HOSIAH HARMAR PENNIMAN, Ph.D., LL.D.,
University of Pennsylvania.

EDWARD PENNOCK,
The American Microscopical Society.

EVERETT F. PHILLIPS, Ph.D.,
The Bureau of Entomology.

H. VLADIMIR P. POLEVOY, Secretary of the Imperial Russian Consulate General, New York,
Society for the Development of Experimental Sciences, Moscow.

CHARLES L. POLLARD, A.M.,
Staten Island Association of Arts and Sciences.

HENRY S. PRATT, Ph.D.,
Haverford College.

JEAN DE PULLIGNY,
École Polytechnique.

RICHARD RATHBUN, Sc.D.,
The Smithsonian Institution.

DAVID REESMAN, M.D.,
Philadelphia Pathological Society.

SAMUEL N. RHOADS,
Delaware Valley Ornithological Club.
THEODORE W. RICHARDS, A.M., LL.D.,
The University of Oxford.
J. T. RORER, Ph.D.,
Colorado College.
ABBOTT LAWRENCE ROTCH, A.M.,
The Boston Society of Natural History,
The Appalachian Mountain Club of Boston,
American Academy of Arts and Sciences.
JOHN G. ROTHERMEL,
The Wagner Free Institute of Science.
WILLIAM E. SAFFORD,
The Botanical Society of Washington.
L. E. SAYRE,
The Kansas Academy of Sciences.
H. L. SCHANTZ, M.D.,
The American Microscopical Society.
CHARLES SCHUCHERT, A.M.,
The Yale University Museum,
The Connecticut Academy of Sciences.
WILLIAM BERRYMAN SCOTT, LL.D., Ph.D., Sc.D.,
Princeton University,
The Geological Society of London.
ISAAC SHARPLESS, Sc.D., LL.D.,
Haverford College.
HENRY SKINNER, M.D., Sc.D.,
Magyar Nemzeti Museum.
ALEXANDER SMITH, Ph.D.,
The Chemical Society of London.
ALLEN J. SMITH, A.M., M.D.,
The Philadelphia Pathological Society.
EDGAR FAHS SMITH, LL.D., Ph.D.,
The University of Pennsylvania.
LEONARD STEJNEGER,
United States National Museum,
Videnskab Selskabet i Kristiania.
NETTIE M. STEVENS, A.M.,
Leland Stanford Junior University.
J. J. STEVENSON, A.M., LL.D.,
The Geological Society of America.
GEORGE B. SUDWORTH,
The United States Forest Service.

JOSEPH SWAIN, M.S., LL.D.,
Swarthmore College,
Leland Stanford Junior University.
WALTER T. SWINGLE, M.D.,
Société Botanique de France.
CHARLES H. TOWNSEND, Hon. Sc.D.,
The New York Aquarium.
FREDERICK W. TRUE, M.D., LL.D.,
The Smithsonian Institution.
SAMUEL M. VAUCLAIN,
The American Philosophical Society.
T. WAYLAND VAUGHAN, A.M., Ph.D.,
The Geological Society of Washington.
MADELENE VERRIE,
Philadelphia High School for Girls.
HENRY L. VIERECK,
The Entomological Society of Washington.
CHARLES D. WALCOTT, Sc.D., LL.D.,
The Smithsonian Institution,
The Carnegie Institution of Washington,
The American Philosophical Society.
JOHN F. WALLACE,
The Western Society of Engineers.
R. M. WARD, M.D.,
The Royal Microscopical Society.
ETHELBERT D. WARFIELD, LL.D.,
Lafayette College.
JOSEPH W. WARREN, M.D.,
Bryn Mawr College.
HENRY S. WASHINGTON, A.M., Ph.D.,
Reale Accademia di Scienze, Lettere ed Arti degli Zelanti di Acireale.
THOMAS L. WATSON, Ph.D.,
The Virginia Geological Survey.
FRANCIS M. WEBSTER, M.D.,
The Entomological Society of Ontario
J. H. M. WEDDERBURN,
The Royal Society of Edinburgh.
WILLIAM M. WHEELER, Ph.D.,
The Entomological Society of America.
MILTON C. WHITAKER, M.S.,
The University of Colorado.
EDWARD E. WILDMAN,
The Philadelphia Central High School.

JOSEPH WILLCOX,
The Wagner Free Institute of Science.
ARTHUR WILLEY, A.M., Sc.D.,
The Marine Biological Association of the United Kingdom.
ALLIE W. WILLIAMS, M.D.,
The Surgeon-General's Office.
GARDNER F. WILLIAMS, M.A., LL.D.,
The South African Association for the Advancement of Science.
EDMUND B. WILSON, LL.D., Ph.D., Sc.D., M.D.,
The Society of American Zoologists.
WILLIAM P. WILSON, Sc.D.,
The Philadelphia Commercial Museums.

SELECTIONS FROM THE LETTERS RECEIVED IN RESPONSE TO THE ANNOUNCEMENT OF THE CENTENARY CELEBRATION.

Académie Royale des Sciences, des Lettres et des Beaux Arts de Belgique.

A l'Académie des Sciences naturelles à Philadelphie:

L'Académie Royale des Sciences, des Lettres et des Beaux Arts de Belgique est très sensible au grand honneur que vous lui avez fait en l'invitant à participer au Jubilé de l'Académie des Sciences naturelles de Philadelphie. Nous avons reçu d'elle, l'agréable mission de vous adresser ses remerciements et ses chaleureuses félicitations.

Heureuse de rappeler les excellentes relations qu'elle a nouées avec elle depuis près d'un siècle, l'Académie Royale de Belgique comprend la légitime fierté avec laquelle l'Académie des Sciences naturelles de Philadelphie doit considérer son histoire durant les cent années écoulées depuis sa fondation. Il lui suffit d'évoquer les noms des savants dont les nombreuses et importantes publications ont paru dans vos Proceedings, dans votre Journal et, dans vos Transactions of the American Entomological Society, pour apprécier les services que votre illustre Académie a rendus aux sciences naturelles dans ses domaines les plus variés.

Notre Académie s'associe donc aux hommages qui seront rendus à votre glorieux passé et aux voeux qui seront formés pour la continuation de votre prospérite.

Puisse votre Académie poursuivre le cours de sa belle et féconde carrière pendant une longue suite d'années! C'est le vœu le plus sincère que forme l'Académie Royale de Belgique.

Le Secrétaire perpétuel de l'Académie,
Le Chevalier Edmond Marchal.

Bruxelles le 19 Mars, 1912.

R. Accademia di Scienze, Lettere ed Arti in Padova.

Padova, li XXVIII, II, MCMXII.

Amplissimo Viro Academiæ Disciplinarum Naturalium Philadelphiæ Præfecto S.:

Cum pergratæ nobis fuerint litteræ tuæ humanissimæ, quibus nobis benigne invitasti, ut Sollemnia sæcularia, quibus Academia Vestra præclarissima natalem suum centesimum omnium cum plausu prosequitur, Vobiscum ipsi concelebraremus, fieri sane non potest, quin et plurimas tibi gratias agamus et maximam semper gratiam, ut debemus, habeamus. Cum vero id aegre ferendum sit, quod Academia nostra per unum aliquem nostrorum sociorum Sollemnibus istis faustissimis interesse non possit, hoc quidem profitemur, nos si non corporibus at certe animis adfuturos esse, te, Vir optime atque honoratissime, cunctamque Academiam istam nobilissimam cui tam digne ipse præes, bonis omnibus prosequentes, ut ad saluberrima artium liberalium omniumque disciplinarum incrementa et progressus communemque civilis consortii utilitatem omnia Vobis fauste feliciter fortunateque eveniant.

Nunc vero cum omnium collegarum verbis tum nostro nomine te summa observantia colentes valere et salvere iubemus.

Praeses
V. Crescini
Secretarius
A. Medin.

I. R. Accademia di Scienze, Lettere ed Arti degli Agiati Rovereto.

Illustrissimo Sigr. Presidente della Accademia di Scienze naturali in Filadelfia:

L'Accademia degli Agiati, onorata del gentile invito di intervenire alla commemorazione del centenario della fondazione di codesta illustre Accademia, prega l'illustrissimo Sigr. Presidente a volerla rappresentare in occasione delle feste del centenario, che rammenterà l'opera data con efficace costanza al progresso delle scienze, dalla secolare Accademia di Filadelfia.

Da parte nostra auguriamo alla consorella che le gloriose sue tradizioni del passato, valgano a rinsaldare il lavoro e lo studio per il bene universale, nella armonica cooperazione di tutti al fine comune.

Noi gradiremo a suo tempo la relazione officiale della commemorazione medesima; intanto preghiamo l'illustrissimo Sigr. Presidente e i congressisti a voler gradire i sentimenti dei nostri più distinti ossequi.

Dall' Aula dell'I. R. Accademia degli Agiati Rovereto, li 28 Febbraio 1912.

Il Presidente:

Dr. Probizer.

L'Accademico Segretario:

Postinger.

AKADEMIA UMIEJETNOŚCI W KRAKOWIE.

Corresponding Secretary, The Academy of Natural Sciences of Philadelphia:

The President and Council of the Cracow Imperial Academy of Sciences beg to offer The Academy of Natural Sciences of Philadelphia their sincere thanks for the invitation which they have received to take part in the celebration of its Centenary Anniversary.

They have much pleasure in transmitting to The Academy of Natural Sciences of Philadelphia, kindest wishes and felicitations on behalf of their own institution; and they beg leave to express, on this opportunity, the feelings of keen sympathy and high appreciation which the students of science in Poland entertain for the work of that illustrious American corporation.

ST. TARNOWSKI,
President,
ULANOWSKI,
General Secretary.

Cracow, March 7th, 1912.

K. Akademie van Wetenschappen te Amsterdam.

The members of the Koninklijke Akademie van Wetenschappen at Amsterdam welcome the opportunity afforded by the celebration of the Centenary of the foundation of The Academy of Natural Sciences of Philadelphia to send their cordial greetings to their colleagues in America.

During the past hundred years The Academy of Natural Sciences of Philadelphia has contributed generously to the progress of scientific thought and has occupied a distinguished place among the institutions of a country which has rapidly placed itself in the van of scientific research.

The constantly increasing intercourse between the scientific world of America and Europe is an earnest testimony of the growth of the spirit of good will and friendly emulation which stimulates the march of progress in all departments of scientific thought.

It is in this spirit that the members of the Koninklijke Akademie of Amsterdam express the confident hope that The Academy of Natural Sciences of Philadelphia will fulfil with equal distinction in the future as in the past its noble mission of enlarging the domain of truth and knowledge.

H. A. Lorentz,
President.
J. D. van der Waals,
Secretary.

Amsterdam, March, 1912.

Exquisitely engrossed and illuminated on folio sheet in a satin-lined cylindrical case with gilt clasps.

ALBERT-LUDWIGS-UNIVERSITÄT, FREIBURG I. BR.

Freiburg i. Br., den 8. März 1912.

An die Akademie der Naturwissenschaften von Philadelphia:

Prorektor und Senat der Albert-Ludwigs-Universität Freiburg i. Br. danken für die freundliche Einladung zu der Jahrhundertfeier am 19–21. März. Zu unserem lebhaften Bedauern müssen wir es uns versagen, an der bedeutsamen Veranstaltung durch einen Delegierten vertreten zu sein, doch begleitet unsere Universität dieses Jubiläum, welches eine an Erfolgen reiche Periode in der Entwickelung der naturwissenschaftlichen Akademie von Philadelphia abschliesst, mit den wärmsten Sympathien und übermittelt der Akademie ihre aufrichtigen Glückwünsche.

Der Prorektor
FABRICIUS.

K. ALBERTUS-UNIVERSITÄT ZU KÖNIGSBERG I PR.

DER PROREKTOR
der Königlichen
ALBERTUS-UNIVERSITÄT

Königsberg i. Pr. den 20 Februar, 1912.

Der hochverehrten Academy of Natural Sciences of Philadelphia, beehre ich mich im Namen und im Auftrage der Königlichen Albertus-Universität zu Königsberg in Preussen unseren ganz ergebensten Dank für die gütige Einladung zu dem Säcular-Jubiläum auszusprechen.

Leider ist es nicht möglich, einen Delegierten zu dem hohen Feste zu senden. Es ist uns aber ein herzliches Bedürfnis, unseren innigen Wünschen wenigstens schriftlich Ausdruck zu geben.

Wer nur irgendwie Kenntnis der Naturwissenschaft besitzt, weiss die hohen Verdienste Ihrer Akademie zu würdigen. Gleich mehreren preussischen Univesitäten ist Ihre Akademie in schwerer, kriegerischer Zeit gegründet worden. Die ersten Mitglieder haben durch diese Stiftung in hervorragender Weise das erhabene Wort betätigt, dass die Pflege der Wissenschaften nicht minder wie der starke Arm des Kriegers zur wahren Blüte eines Staates gehört. Und dieser Ideale, auf die Forschung gerichtete Sinn ist in Ihrer Akademie mit Treue gepflegt und immer weiter ausgebildet worden. Von Ihrer Stadt, die schon in ihrem Namen von einem auf die höchste Humanität gerichteten Streben Zeugnis gibt, ist eine Fülle wissenschaftlicher Erkenntnis ausgegangen; die Forschungen, die Sie in Ihrem JOURNAL und in Ihren PROCEEDINGS niedergelegt haben, sind das Gemeingut der gelehrten Welt geworden. Möge Ihre ruhmreiche Akademie noch viele Jahrhunderte blühen und der Wissenschaft immer neue und reiche Schätze bescheeren und dadurch auch die innere unzerstörbare Gemeinsamkeit der Nationen fördern.

Die Albertus-Universität wird alle Zeit mit Dankbarkeit und herzlicher Sympathie der Academy of Natural Sciences gedenken.

In ausgezeichnetster Verehrung

ganz ergebenst.
KRAUSKE.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Smithsonian Institution, Washington, D. C.,
March 16, 1912.

The American Association for the Advancement of Science, through its delegates appointed for this purpose, presents to The Academy of Natural Sciences of Philadelphia its heartiest good wishes on the occasion of the celebration of the Centenary Anniversary of the founding of the Academy.

It further congratulates the Academy on the admirable work it has accomplished and upon its prospect for more good work in the future.

By L. O. HOWARD,
Permanent Secretary.
Through Delegates Appointed.

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS.

Dallas, Texas, March 11, 1912.

Corresponding Secretary, The Academy of Natural Sciences of Philadelphia:

Sir: I have the honor to acknowledge the receipt of the invitation of The Academy of Natural Sciences of Philadelphia to the American Association of Economic Entomologists to be represented at the Centenary Anniversary ceremonies soon to be held in Philadelphia. In behalf of this Association I desire to thank the Academy for the honor of this invitation.

From the beginning of its long and active career The Academy of Natural Sciences of Philadelphia has fostered and encouraged entomology. Many of the most prominent contributors to the science in America have been connected with the Academy. Many others who have played conspicuous parts in American economic entomology have received their inspiration from the work of the Academy. In fact, there is not an entomologist in the United States who does not, directly or indirectly, owe a debt of gratitude to the Academy.

Doctor L. O. Howard, of Washington, has been requested to represent this Association at the coming ceremonies and to express its good wishes, high appreciation of the uniform good work it has done in the advancement of science, and its hope that this work will continue to grow.

Very respectfully
W. D. HUNTER,
President.

American Microscopical Society.

The James Millikan University, Decatur, Ills., March 15, 1912.

The American Microscopical Society, in common with other similar societies the world over, rejoices in the century of honorable and useful activity of The Academy of Natural Sciences of Philadelphia, and extends to you its greetings and congratulations on the completion of one hundred years of productive effort. We confidently hope that the century upon which you are now entering will be one of eminent success and influence.

T. W. Galloway,
Secretary, American Microscopical Society.

The American Museum of Natural History, New York.

To the President and Board of Trustees of The Academy of Natural Sciences of Philadelphia, Greeting:

The President and Board of Trustees of The American Museum of Natural History, through their delegate, Doctor Frederic A. Lucas, desire to tender to The Academy of Natural Sciences of Philadelphia, their congratulations on the completion of a century of active and earnest work.

In this, the New World, few institutions can claim so long a career as yours, few are so important, none can number among its members a more brilliant galaxy of men of science than that which includes the names of Morton, Wistar, Leidy, and Cope.

May the progress of the Academy be ever upwards, may its career be as prosperous, as vigorous in the future as in the past; may it ever stand, as it has done for an hundred years, for all that is best in the cause of science in America.

Henry Fairfield Osborn,
President.

Archer M. Huntington,
Secretary.

New York City, March the eighteenth, 1912.

American Philosophical Society.

The American Philosophical Society to The Academy of Natural Sciences of Philadelphia, Greeting:

The American Philosophical Society presents its heartiest congratulations on this Hundredth Anniversary of the foundation of the Academy. A kindred society recognizes the high purpose of the founders of the Academy, rejoices in the tenacity with which that purpose has been fulfilled, and bespeaks a long continuation of prosperity and usefulness for it.

With much good will the American Philosophical Society sends representatives to do honor to this Anniversary Celebration.

Given at Philadelphia this nineteenth day of March in the year Nineteen Hundred and Twelve.

William W. Keen,
President.
Attest: I. Minis Hays,
Secretary.

Beautifully printed on a folio sheet.

Ateneo Veneto.

Venezia, li 23 February, 1912.

Honoured Sir:

The Ateneo Veneto gratefully accepts the kind invitation of The Academy of Natural Sciences of Philadelphia, but, being unable to send a special deputy to the celebration of your centenary festivities, we beg your illustrious President to represent our Academy.

A hundred years have lately elapsed since the foundation of the Ateneo Veneto that has always been faithful to its scientific, artistic, and patriotic programme, and it very gladly hails the Hundredth Anniversary of its sister Academy, with hearty wishes for an ever prosperous, active, and fruitful life, like that to which your acts (records) of these hundred years are witness.

With sincere congratulations and best respects,

The President,
Filippo Nani Mocenigo.

To the Secretary of the Academy of Natural Sciences of Philadelphia.

K. BAYERISCHE AKADEMIE DER WISSENSCHAFTEN.

München, den 5 März 1912.

An die Academy of Natural Sciences of Philadelphia:

Die K. bayerische Akademie der Wissenschaften bedauert, zur Hundertjahrfeier der ältesten naturwissenschaftlichen Gesellschaft der Vereinigten Staaten keinen Vertreter schicken zu können. Verknüpfen sie doch mit ihr nicht nur die allgemeinen, völkerverbindenden Interessen der Wissenschaft, sondern auch seit vielen Jahren ein reger, stets mit Freude entgegengenommener Austausch der Gelehrten Schriften.

Die K. bayerische Akademie der Wissenschaften beglückwünscht die Academy of Natural Sciences zu der eifrigen Arbeit, die sie in ihren PROCEEDINGS und JOURNAL seit langem für die Wissenschaft leistet und wünscht ihr eine gedeihliche und kräftige Weiterentwicklung.

Mit ausgezeichneter Hochachtung,

DR. VON HEIGEL,
Präsident.

Botanischer Verein der Provinz Brandenburg.

Dahlem, den 7 März, 1912.

Der Academy of Natural Sciences of Philadelphia dankt der Botanische Verein der Provinz Brandenburg verbindlichst für die Einladung zur Feier des 100jährigen Bestehens der Akademie.

Bei Eintritt eines so seltenen Festes setzen Freunde sowie Vertreter befreundeter Gesellschaften eine Ehre darein im Kreise der feiernden Körperschaft persönlich zu erscheinen. Leider kann jedoch zur Zeit kein Mitglied des botanischen Vereins es ermöglichen, die grosse Entfernung zwischen den Sitzen beider Körperschaften zu überwinden und der Akademie an ihrem Ehrentage die Glückwünsche des Vereins mündlich darzubringen. Deshalb bittet der Verein, der seit langen Jahren in den freundschaftlichsten Beziehungen zu der Akademie steht und seine Schriften mit den ihrigen tauscht, ihr durch dieses Schreiben die herzlichsten und aufrichtigsten Wünsche aussprechen zu dürfen für ihr weiteres Gedeihen, für immer grössere und erfolgreichere Ausdehnung ihrer Arbeiten und Bestrebungen. Denn wie in der Natur selbst nichts still steht, sondern alles sich ständig zu entwickeln strebt, so streben auch die naturwissenschaftlichen Gesellschaften dauernd danach, sich immer reicher zu entfalten, immer neuen, umfassenderen Aufgaben sich zu widmen, immer höhere Ziele sich zu stecken.

Die von der Akademie seit 100 Jahren geleistete, auf den verschiedensten Gebieten so erfolgreiche Arbeit bürgt dafür, dass sie in ihrer Bedeutung immer zunehmen, dass sie die wissenschaftliche Welt auch ferner mit vielen wertvollen Leistungen beschenken und bereichern wird. Der botanische Verein sieht zwar seine Hauptaufgabe darin, seine Heimatprovinz botanisch zu erforschen, er ist sich aber stets bewusst gewesen, dass er diese Aufgabe ohne ständige Fühlung mit der Botanik nicht blos, sondern auch mit der gesamten Naturwissenschaft nicht in befriedigender Weise erfüllen kann. Deshalb weiss er die weit umfassendere Tätigkeit der Akademie sehr wohl zu schätzen und zu würdigen, und es wird ihm zur freudigen Genugtuung gereichen, wenn er auch in Zukunft aus seiner Beziehungen zu einer so alten und angesehenen Körperschaft Nutzen ziehen und ihr zeigen darf, wie wertvoll ihm diese alte freundschaftliche Verbindung ist.

Die Akademie zu Philadelphia möge wachsen, blühen und gedeihen.

Der Vorstand des Botanischen Vereins der Provinz Brandenburg J. A.

Emil Koehne.

British Museum of Natural History.

Cromwell Road, London, S. W.

The British Museum of Natural History, London, hereby conveys to The Academy of Natural Sciences of Philadelphia its warmest congratulations on the occasion of the celebration of the Academy's Centenary Anniversary. The British Museum of Natural History extends to the Academy the most sincere wishes for the future prosperity and well-being of the Academy and its earnest desire that the very friendly relations which have so long existed between the two institutions may be maintained and strengthened as the years go by for their mutual benefit and the cultivation of the natural sciences.

In the regretted absence of a representative the British Museum of Natural History hopes that The Academy of Natural Sciences of Philadelphia will accept this assurance of the cordial good will of the Museum.

L. Fletcher,
Director.

March 13, 1912.

BUFFALO SOCIETY OF NATURAL SCIENCES.

February 14, 1912.

Corresponding Secretary of The Academy of Natural Sciences of Philadelphia.

Dear Sir:

At a meeting of the Board of Managers of the Buffalo Society of Natural Sciences, held Friday evening, February 9, 1912, your courteous invitation to the Society that it should be represented at the One Hundredth Anniversary of the founding of your Academy was presented to the Board and the following resolution was unanimously adopted: Resolved: That this Society extend to The Academy of Natural Sciences of Philadelphia its most hearty congratulations upon the near approaching Centenary Anniversary of its founding and with such congratulations to express the sincere feeling of respect and appreciation which, in common with all workers in natural science, this Society feels for the splendid and valuable work accomplished by the Academy during the one hundred years of its useful existence and to bespeak for it a further long continuance of its active and honorable life.

By direction of the Board it gives me great pleasure to transmit to you this resolution which now appears upon our minutes.

Very respectfully yours,

HENRY R. HOWLAND,

Superintendent, Buffalo Society of Natural Sciences.

BUREAU OF ENTOMOLOGY, UNITED STATES DEPARTMENT OF AGRICULTURE.

Washington, D. C., March 16, 1912.

To The Academy of Natural Sciences of Philadelphia, Pa.

All the members of the staff of the Bureau of Entomology of the United States Department of Agriculture join in hearty congratulations to the Academy on the occasion of its celebration on its One-hundredth Birthday. No body of men appreciates more highly the high character of the work done by the Academy than does this force, and none can congratulate the Academy more heartily on its present commanding position in the field of American Science.

For the Bureau,

L. O. HOWARD,

Chief.

The Canadian Institute.

198 College St., Toronto, March 16, 1912.

Corresponding Secretary, The Academy of Natural Science of Philadelphia.

Dear Sir:

I beg to thank you for your kind invitation to the Canadian Institute to be represented at the Centenary Anniversary of the Academy, and I greatly regret that it is impossible for me or any of my associates to be present with you.

You have had a long and successful career, and the President and Members of the Canadian Institute extend you most hearty greetings, with the hope that your future achievements may not only equal, but may far outdo, your accomplishments in the past.

Yours sincerely,

J. B. Tyrrell,

President, Canadian Institute.

Carnegie Institution of Washington.

The Trustees and the Investigators of the Carnegie Institution of Washington extend greetings and congratulations to The Academy of Natural Sciences of Philadelphia on the occasion of the celebration of its One hundredth Anniversary.

The century of progress achieved by the Academy in the cultivation of the Natural Sciences commands admiration for the devotion of our predecessors, gives confidence in the fruitfulness of the labors of our contemporaries, and warrants sanguine expectations for continued advances by our successors.

Robert S. Woodward,

President.

On a beautifully engrossed and illuminated sheet.

THE CARNEGIE MUSEUM (DEPARTMENT OF THE CARNEGIE INSTITUTE).

Pittsburgh, March 19, 1912.

To The Academy of Natural Sciences of Philadelphia:

On behalf of the Carnegie Museum, which represents at the headwaters of the Ohio the same forms of activity which are represented by The Academy of Natural Sciences upon the banks of the Delaware, we have the honor of extending our sincere congratulations upon your first Centenary, and we desire to express the hope that many centenaries, as fruitful as has been the first, may follow. We have with pride caused to be carved upon our walls, where all can read it, the name of your own honored and immortal Leidy, for whose achievements we are no less grateful than you.

GEO. H. CLAPP,
Chairman of the Committee of the Institute upon the Affairs of the Museum,
W. J. HOLLAND,
Director.

Beautifully engrossed.

THE CATHOLIC UNIVERSITY OF AMERICA.

Office of the Rector,
The Catholic University of America, Washington, D. C.

The Catholic University of America sends its heartiest congratulations to The Academy of Natural Sciences of Philadelphia on the occasion of the celebration of its first Centenary. The foundation of the Academy is probably the most important event in the history of American science, since it marks the initial steps in the path of intellectual and material development that has kept ever broadening until it has become one of the world's splendid highways of progress and culture. We are certain that in the century to come the Academy will continue its noble work of inspiration and encouragement in the vast province of the natural sciences; above all that it will help materially to keep them correlated to all that is truly beautiful and uplifting in the social, political, and religious life of our American mankind.

With best wishes, I remain,
Very sincerely yours,
THOMAS J. SHAHAN,
Rector.

The Academy of Natural Sciences of Philadelphia.

ČESKÁ AKADEMIE CÍSAŘE FRANTISKA JOSEFA PRO VĚDY, SLOVESNOST A UMENI.

Imperatoris Francisci Josephi Academia Scientiarum, litterarum, artium Bohemica Societati Naturalium Scientiarum Philadelphiensi S. P. D.

Centum anni peracti sunt, ex quo nata est celeberrima Societas Vestra. Per hoc omne temporis spatium sodales Societatis Vestræ multa et magna strenui laboris, studii doctissimi, acuminis admirandi ediderunt documenta scriptisque egregiis non solum de Vestræ Societatis laude et gloria, sed etiam de universi generis humani litteris et artibus optime meruerunt.

Quapropter iure ac merito memoriam originis Societatis Vestræ hoc anno recolitis et natales eius centesimos per hosce dies sollemniter celebratis. Cui sollemni cum adesse, id quod magnopere dolemus, non possimus per litteras saltem Vos, viros doctissimos salvere iubemus, vere et ex animo precantes, ut Societati Scientiarum Naturalium Philadelphiensi etiam proximis temporibus cuncta prosperrime eveniant eiusque nomen et gloria per omnes gentes terrasque in dies crescat atque augeatur.

Dabamus Pragæ in Bohemia Kal. Martiis MCMXII.

A. RANDA
praeses Academiæ.
C. VRBA
Secretarius Academiæ.

Beautifully illuminated and engrossed on folded sheet.

C. K. ČESKÁ UNIVERSITA KARLO-FERDINANDOVA V PRAZE.

No. 776, Sen. 1911–12.

The Imperial and Royal Czech Charles and Ferdinand University of Prague, the oldest University of Central Europe, sends to The Academy of Natural Sciences of Philadelphia, on the eve of the day on which the Academy will have completed one hundred years of its activity, the most hearty salutations and sincere congratulations. May the illustrious Academy flourish and prosper through many centuries to the advantage of Science and to the benefit of the American nation and the whole of humanity.

Dated in Prague this Fifth day of March, 1912, in the five hundred and sixty-fourth year from the foundation of the Charles and Ferdinand University.

J. CELAKOVSKY,
Rector of the University.
J. CECH,
Chief Clerk of the University.

CINCINNATI SOCIETY OF NATURAL HISTORY.

Cincinnati, O., Feb. 10, 1912.

To The Academy of Natural Sciences of Philadelphia:

The Cincinnati Society of Natural History has received your invitation to be present at the celebration of your Centenary Anniversary. The Society highly appreciates the honor conferred. We certainly feel the most profound respect and admiration for your venerable institution, not only because of the illustrious students who have been associated with it, but also because of the high character of the scientific work with which you have enriched the field of natural history in America.

Accept our sincere congratulations.

CHAS. DURY,
Secretary.

College of Physicians of Philadelphia.

The College of Physicians of Philadelphia brings greetings to The Academy of Natural Sciences of Philadelphia and presents its congratulations on this the Centenary of its Foundation.

The College is proud of the brilliant record of the Academy in these hundred years, rejoicing that among its members are a number, and some of its most distinguished, who were also Fellows of the College.

Both claim the immortal Leidy, though the College grants that the Academy was the object of his fondest love and reflected his greater glory.

The College hopes that this century of growth which finds the Academy so strong and vigorous may be succeeded by many others full of honor for itself and rich in benefits to all mankind.

Richard A. Cleeman,
Delegate from the College of Physicians of Philadelphia.

March 19, 1912.
Engrossed.

Conservatoire et Jardins Botaniques (Herbier Delessert).

La Console, Route de Lausanne, 92, Ville de Genève, 1 Mars, 1912.

The Academy of Natural Sciences of Philadelphia:

Monsieur le President et Messieurs:

La distance ne nous permet malheureussment pas de réponde à l'aimable invitation que vous nous avez adressée pour le Centenaire de votre Academie.

Nous n'en tenons pas moins à vous dire votre admiration pour les beaux travaux scientifiques exécutés depuis un siècle au sein de votre Académie, et à vous présenter nos voeux les plus chaleureux pour la brillante continuation de ses efforts.

Veuillez agréer, Monsieur le President et Messieurs, l'expression de notre haute considération.

Dr. John Briquet,
Directeur.

Deutsche Geologische Gesellschaft.

Berlin, im März 1912.

To The Academy of Natural Sciences of Philadelphia:

Der hochverehrten Academy of Natural Sciences of Philadelphia sprechen wir für die uns ehrende Einladung zur Hundertjahrfeier unseren verbindlichsten Dank aus. Wenn wir auch nicht in der Lage sind, zu Ihrem Jubelfest einen Vertreter unserer Gesellschaft zu senden, so werden wir doch in den Tagen vom 19. bis 21. März dieses Jahres mit unseren Gedanken bei Ihnen sein und Ihnen unsere herzlichsten Glückwünsche widmen.

Die Academy of Natural Sciences of Philadelphia ist die älteste naturwissenschaftliche Gesellschaft der Vereinigten Staaten Nordamerikas und sie hat an dem grofsen Aufschwung, den die Naturwissenschaften in dem verflossenen Jahrhundert erlebt haben, einen sehr bedeutenden Anteil gehabt.

Durch die Schaffung einer ausgezeichneten Bibliothek, durch die Begründung eines hervorragenden naturwissenschaftlichen Museums, durch die Veröffentlichung bedeutsamer Arbeiten, die seit dem Jahre 1817 im Journal und ausserdem seit 1841 in den Proceedings erschienen sind, sowie durch die Verleihung von Stipendien an junge Gelehrte hat Ihre Gesellschaft die Naturwissenschaften in hohem Grade gefördert.

Indem wir dies dankbar anerkennen, wünschen wir Ihrer Academy für das neue Jahrhundert, in das sie nun eintritt, ein kräftiges Blühen, Wachsen und Gedeihen!

Im Namen der Deutschen Geologischen Gesellschaft zu Berlin,

F. Wahnschaffe,
Vorsitzender.

Deutscher Naturwissenschaftlich-Medizinischer Verein für Böhmen Lotos.

Der Deutsch. Naturwiss. Medizin. Verein für Böhmen ΛΩΤΟΣ in Prag sendet der ehrwürdigen Academy of Natural Sciences of Philadelphia anlässlich der hundertsten Wiederkehr ihres Gründungstages, würdigend die Verdienste, die sich Dieselbe in dieser Zeit als hervorragende Stütze und rastlose Pflegerin der Naturwissenschaften erworben hat, die besten Wünsche für die Zukunft und ein ebenso erfolgreiches Wirken ad aeternum!

Prof. Dr. R. Spitaler,
m. p.
Doc. Dr. L. Freund,
m. p.

Prag, den 5 März 1912.
Beautifully printed on an ornamented sheet.

Entomological Society of London.

To The Academy of Natural Sciences of Philadelphia:

On behalf of the Entomological Society of London we offer you sincere congratulations on the completion of one hundred years of distinguished and fruitful labour in the cause of Science, and assure you that we appreciate, and have accepted with gratitude, the honour of being represented at the Conference to which you have invited us.

The Centenary of a great scientific institution cannot but arouse some amount of sympathetic interest in every association of scientific workers, but we feel that, as entomologists, we have special reason to be interested in the fortunes of your Academy, since we understand that for many years our favorite branch of natural science has received from it no small share of valuable encouragement and support; that in 1875 our sister society, first known as The Entomological Society of Philadelphia, received permission to assemble under your hospitable roof; and that subsequently it became incorporated as a Section of the Academy itself.

In all sincerity, and as no mere formal compliment, we are glad to offer you this tribute to our gratitude, respect, and good will, and to express the hope that the future of your Academy may be as useful and as honorable as its past.

Francis David Morice,
President Ent. Soc. London,
Albert Hugh Jones,
Jno. Hartley Durrant,
Vice-Presidents,
James J. Walker,
George Wheeler,
Hon. Secretaries.

London, March 13, 1912.
Engrossed on parchment.

THE ENTOMOLOGICAL SOCIETY OF WASHINGTON,

United States National Museum, Washington, D. C., February 19, 1912.

The Academy of Natural Science of Philadelphia.

Gentlemen:

In the spirit of admiration and fraternity the Entomological Society of Washington welcomes the opportunity to present its heartiest congratulations to The Academy of Natural Sciences of Philadelphia on the occasion of the celebration of its one hundred years of activity.

Without the fostering care of the Academy, Thomas Say, the father of American entomology, could never have prepared and published his descriptions. The share of the Academy in supporting Say in his work of describing American insects in America will always be gratefully remembered by entomologists.

As an entomologist turns the pages of the early volumes of the Academy and sees the names of Say, the two Lecontes, Haldeman, Clemens, Melsheimer, Uhler, Ziegler, Osten Sacken, and Crotch, he recognizes the beneficence of the Academy in providing a medium for publication before there were any entomological journals. The appearance of these papers under the auspices of the Academy gave them an appreciation abroad that they would not otherwise have enjoyed. And today, when there are many entomological journals, the pages of the PROCEEDINGS of the Academy are freely used for the publication of entomological articles.

The Academy was the first institution in America to offer accommodations for insect collections; and now that its benign influence shelters the priceless collections of the American Entomological Society, it has become one of the few shrines that every entomologist loves to visit, and none more than the members of the Entomological Society of Washington appreciate the entomological usefulness of the Academy, and wish it a long and increasingly successful career.

Very sincerely,

A. L. QUAINTANCE,
President.

S. A. ROHWER,
Corresponding Secretary.

Franklin Institute of the State of Pennsylvania.

The Franklin Institute of the State of Pennsylvania, for the promotion of the Mechanic Arts, to the President, Council, and Members of The Academy of Natural Sciences of Philadelphia:

It is with intimate and sincere satisfaction that the President, Officers and Members of the Franklin Institute embrace this opportunity of extending to you their warm congratulations upon the completion of a century of brilliant and useful work in the wide domain of Natural Science. Organized twelve years later for the promotion of Physical Science and its application in the Arts, and similarly environed, this Institute has shared with you the intelligent and sustained support of the citizens of Philadelphia, and it is from this support, generously continued, that we confidently look forward to even greater successes for you in the future, than those which have marked your splendid past.

Henry Howson,
President.
R. B. Owens,
Secretary.

Philadelphia, March 19, 1912.
Beautifully engrossed on ornamented sheet.

K. Frederiks Universitet, Kristiania.

To The Academy of Natural Sciences of Philadelphia:

The Royal Frederik University of Christiania, Norway, has the honor to acknowledge receipt of the invitation of The Academy of Natural Sciences of Philadelphia to be represented at the Centenary Anniversary of said Academy on the 19th, 20th, and 21st of March of this year, and to express high appreciation of the courteous attention.

Minister Helmer Bryn, LL.B. of our University, Norwegian Minister in the United States of America, Washington, D. C., has been chosen as the representative of our University to be present on the aforesaid occasion.

We also take advantage of the opportunity to convey our best wishes for the prosperity and welfare of the venerable Academy of Natural Sciences, and to express our conviction that it will be in the future, as it has been in the past, one of the justly distinguished institutions of Science of the Republic.

Bredo Morgenstierne,
Rector.

Ch. Aug. Orland,
Secretary.

Christiania, February 18, 1912.

Printed on folded sheet in a crimson leather ornamented portfolio.

ROYAL GEOGRAPHICAL SOCIETY.

1, Savile Row, Burlington Gardens, London, W., February 14, 1912.

To the President, The Academy of Natural Sciences of Philadelphia.

Sir:

On my own behalf as President, and on behalf of the Council of the Royal Geographical Society, I beg to offer you our warmest congratulations on the celebration of the Centenary of the foundation of The Academy of Natural Sciences of Philadelphia.

It reflects the highest credit on the United States of America that so early in its career as an independent State, an institution should have been established for the pursuit of natural knowledge, and as a centre of culture and enlightenment, in the midst of a population which was naturally strenuous in the development of the material resources of a great country. The Academy of Natural Sciences of Philadelphia soon achieved and has throughout maintained a position as one of the great scientific societies of the world, and its publications contain many contributions of original value in the various departments of scientific investigation, as well as of practical importance to humanity at large and to America in particular.

Our earnest wish is that the Academy may long continue to carry out with as much success as in the past, its beneficent services to science and to its country.

I have the honour to be, Sir,

Yours most sincerely,

CURZON OF KEDLESTON,

President, Royal Geographical Society.

Geographical Society of Philadelphia.

400 Witherspoon Bldg., Philadelphia, March 1, 1912.

Samuel G. Dixon, M.D., LL.D., President, The Academy of Natural Sciences of Philadelphia, Pa.

Sir:

On behalf of the Council of the Geographical Society of Philadelphia, I beg to present respectful greetings and congratulations on the occasion of the Centenary Celebration of The Academy of Natural Sciences of Philadelphia.

Recalling the fact that our own society was organized twenty-two years ago under the name of the Geographical Club by officers and members of the Academy, and had its home for years within the walls of your institution—we have viewed with filial pride the continued distinction, usefulness, and prosperity of the Academy.

In the hope that the Academy will continue to represent the best traditions of scientific scholarship and achievement in Philadelphia and may extend its field of usefulness in this community, I beg to remain, Sir,

Very sincerely yours,

Emory R. Johnson,

President, Geographical Society of Philadelphia.

K. K. Geographische Gesellschaft, Wien.

Präsidium der K. K. Geographischen Gesellschaft
in Wien, I., Wollzeile 33.

The Academy of Natural Sciences of Philadelphia:

Das Präsidium der k. k. Geographischen Gesellschaft dankt verbindlich für die freundliche Einladung zur Feier des hundertjährigen Bestandes der sehr geehrten Akademie und bedauert mitteilen zu müssen, dass leider Niemand aus dem Collegium in der Lage sich befindet, dieser Einladung Folge zu leisten und an dieser erhebenden Feier persönlich teilzunehmen.

Das gefertigte Präsidium beehrt sich daher die verehrte Akademie zu ihrer hundertjährigen Jubelfeier schriftlich zu beglückwünschen und dem Wunsche Ausdruck zu geben, dass die Academy of Natural Sciences of Philadelphia mit gleichen Erfolgen weiter wirken möge zum Besten der Naturwissenschaften!

Der Präsident:
Prof. Eugen Oberhummer
Der General-Sekretär:
Dr. Gallina.

Wien, am 4. Märx 1912.

Geological Society of America.

The Geological Society of America sends heartiest congratulations to The Academy of Natural Sciences of Philadelphia on the occasion of its Centennial Celebration.

As we recall the great services rendered by members of the Academy to geology and related branches of science, we are moved to express the hope that this close of the first century is but the beginning of your youth, and that you may long continue to contribute to the advancement of knowledge.

H. L. Fairchild,
President,
Edmund Otis Hovey,
Secretary.

New York, 19 March, 1912.

K. k. Geologische Reichsanstalt, Wien.

Die kaiserliche konigliche Geologische Reichsanstalt begrüsst auf das herzlichste die Academy of Natural Sciences of Philadelphia zur Feier ihres hundertjährigen Bestandes und beglückwünscht dieselbe zu der Summe von Arbeit, welche während dieses Zeitraumes geleistet worden ist, in der Hoffnung, dass die Bestrebungen der Akademie in weiterer Zukunft von gleichem Erfolge begleitet sein werden.

Der Direktor,
Dr. Emil Tietze.

Wien, im Marz 1912.
Beautifully engrossed on artistically decorated folio sheet.

Geologists' Association of London.

University College, London.

The Geologists' Association of London which has recently celebrated its 50th Anniversary sends its cordial Greetings to The Academy of Natural Sciences of Philadelphia on the completion of a hundred years of its successful existence during the course of which its publications have made known to the world numerous and important contributions to every branch of Natural History including Palæontology in which, as is natural, this Association feels most keenly its indebtedness to the good work which the Academy has done.

John W. Evans,
President.

9th March, 1912.
Engrossed on parchment.

K. GEOLOGISCHE LANDESANSTALT, BERLIN.

Invalidenstrasse 44, Berlin, den 4 März 1912.

Die Königlich Preussische Geologische Landesanstalt begrüsst von ganzem Herzen die altehrwürdige Akademie der Naturwissenschaften zu Philadelphia zur Feier ihres hundertjährigen Bestehens und bringt ihr dazu die besten Wünsche dar für eine weitere erspriessliche Tätigkeit zum Nutzen der gesamten Naturwissenschaft und des von uns besonders gepflegten Zweiges der Geologie. In den langen Reihen der von der Akademie veröffentlichten PROCEEDINGS und des JOURNAL sind eine ungewöhnlich grosse Zahl von Arbeiten aus dem Gebiete der Mineralogie, Geologie und Paläontologie veröffentlicht worden und die scharfsinnigsten Geister, die feinsten Köpfe der nordamerikanischen Gelehrtenrepublik, Männer wie Cope, Leidy, Frazer, Heilprin, Osborn, Genth, und viele andere durfte die Akademie zu den ihren zählen. Durch die Gründung einer selbst für die grosszügigen Verhältnisse der Union hervorragenden Bibliothek und Sammlung hat die Akademie zur Förderung der Wissenschaft beigetragen und durch die Gewährung reicher Geldmittel manches wissenschaftliche Unternehmen, manche erfolgreiche Forschungsexpedition in die Wege geleitet. So können auch wir nur mit den grössten Sympathien der Tätigkeit der Akademie im abgelaufenen Jahrhundert gedenken und mit den lebhaftesten Wünschen ihre weitere Entwickelung in der Zukunft begleiten. Glückauf.

Der Direktor
BEYSCHLAG

An die Akademie der Naturwissenschaften zu Philadelphia.

GEORG-AUGUST-UNIVERSITÄT, GÖTTINGEN.

DER PROREKTOR
DER
GEORG AUGUST-UNIVERSITÄT.

Göttingen, den 2. März, 1912.

Der Academy of Natural Sciences in Philadelphia sendet zur Feier ihres 100 Jahr-Bestehens die Georg-August-Universität in Göttingen ihre ehrerbietigen und herzlichen Glückwünsche.

Sie gedenkt dabei in aufrichtiger Sympathie der zahlreichen Fäden, welche die wissenschaftliche Forschung und Lehre in Nordamerika mit den gleichen Arbeiten in Deutschland verknüpfen, und spricht die Hoffnung aus, dass diese Fäden durch die Entwicklung des zweiten Jahrhunderts im Leben der Academy nur noch gefestigt werden möchten. Sie wünscht der Academy, die an ehrwürdigem Alter an der Spitze aller wissenschaftlichen Körperschaften der United States steht, ein weiteres jugendliches Blühen und Gedeihen zur Förderung der Wissenschaft, zu deren Dienst sich alle Kulturvölker vereinigt haben.

VOIGT.

An die Academy of Natural Sciences of Philadelphia.

K. Gesellschaft der Wissenschaften zu Göttingen.

Göttingen, den 6 März 1912.

Der hochansehnlichen Academy of Natural Sciences danken wir verbindlichst für die Anzeige, dass diese Academie die Jahrhundertfeier ihrer Stiftung begehen wird, und für die sehr geschätzte Einladung, mit der sie uns zur Teilnahme an dieser Feier beehrt hat.

Neben die ältere Philosophische Gesellschaft in Philadelphia trat vor einem Jahrhundert die Academie für Naturwissenschaften mit der bestimmten Aufgabe an der kräftig einsetzenden Arbeit für die Erkennung der Naturerscheinungen, die ein einigendes Band der gleichstrebenden Völker wurde, zielbewusst und erfolgreich teilzunehmen. Und wenige Jahre danach brachte sie den Erfolg solcher Arbeit mit dem ersten Bande ihrer Veröffentlichungen, deren ununterbrochene Reihe durch das Jahrhundert von dem werktätigen Leben der Genossenschaft wissenschaftlicher Männer Zeugnis gegeben hat. Durch langjährigen Schriftenaustausch mit ihr verbunden, hat unsere Gesellschaft von dort Belehrung und Anregung erhalten. Dankbar für solche Verbindung bringen wir heute der jubilirenden Akademie zu einer erfolgreichen Zukunft für die die Vergangenheit zuverlässige Bürgerschaft bietet, die aufrichtigsten Glückwünsche.

Der Vorsitzende Sekretär
E. Ehlers.

An die Academy of Natural Sciences of Philadelphia.

HEIDELBERGER AKADEMIE DER WISSENSCHAFTEN-STIFTUNG HEINRICH LANZ.

Der altehrwürdigen Akademie der Naturwissenschaften in Philadelphia, welche der erst vor wenigen Jahren durch den Edelsinn eines Badischen Grossindustriellen gegründeten Heidelberger Akademie der Wissenschaften die Ehre erwiesen, sie zu ihren Jubiläumsfestlichkeiten einzuladen, senden wir herzlichen Dank und besten Glückwunsch. Möge es Ihrer Akademie, deren hochverehrte Forscher im Laufe des vorigen Jahrhunderts so viel zu dem wunderbaren Emporblühen der Naturwissenschaften und dem rastlosen Fortschreiten genialer Technik beigetragen haben, auch ferner vergönnt sein, Ihr grosses und in seiner modernen Entwicklung bewundertes Land in enger Verbindung mit den Instituten und gelehrten Gesellschaften Deutschlands, welche in die Pflege der Naturwissenschaften ihren Stolz setzen, an der Entwicklung des Menschengeschlechts ruhmreichen Anteil nehmen zu lassen.

In Verehrung
LEO KOENIGSBERGER,
geschäftsführender Secretär.

Heidelberg, den 2. März 1912.

HRVATSKO NARAVOSLOVNO DRŮSTVO.

Zagreb, dne 22–II 1912.

To The Academy of Natural Sciences of Philadelphia:

We return our best thanks for your kind invitation to your remarkable festival. We are very sorry for not being able to be witnesses through our representatives of your magnificent festival of civilization and sciences, and therefore we take the liberty in this way to congratulate the Academy and express our hope that the Academy will successfully continue its useful activity for the welfare of mankind and advancement of the international sciences.

DR. L. CAR,
President.
IVANU KRMPOTIĆU,
Secretary.

INSTITUT OCÉANOGRAPHIQUE.

Fondation Albert Ier, Prince de Monaco, Monaco, le 29 1 1912.

Monsieur:

Je m'empresse de vous accuser réception de l'invitation adressée au Musée océanographique de Monaco de se faire représenter à la cérémonie du centenaire de The Academy of Natural Sciences of Philadelphia. Je vous prie de vouloir bien transmettre a l'Académie les sincères remerciements du Musée océanographique pour l'honneur qui lui est ainsi fait; le Musée regrette de ne pouvoir envoyer à Philadelphie, à cette occasion, un de ses représentants, mais il vous prie de vouloir bien offrir en son nom, a l'Académie, ses meilleurs souhaits de prospérité et ses plus vives félicitations à l'occasion de son centenaire, sans oublier la manifestation du désir de voir continuer dans l'avenir, comme par le passé, les meilleures relations entre l'Académie et le Musée océanographique.

Veuillez agréer, Monsieur, l'expression de mes sentiments les plus distingués.

Le Directeur
J. RICHARD.

To the Corresponding Secretary, The Academy of Natural Science of Philadelphia.

INSTITUT PASTEUR.

25, Rue Dutot, Paris, le 8 Mars 1912.

À Monsieur le Président de l'Académie des Sciences Naturelles de Philadelphia.

Monsieur le Président: Le Conseil de l'Institut est très honoré de l'invitation que vous lui adressez de se faire représenter à la celebration du centenaire de l'Académie des Sciences Naturelles de Philadelphie. Je regrette que les exigences de l'enseignement empèchent l'un de ses membres de se rendre aux Etats Unis pour porter à votre illustre Compagnie, les félicitations méritées par un siècle de dévouement à la Science. Je me charge de vous exprimer la gratitude qu'il éprouve pour une association qui s'est consacrée à la recherche de la vérité avec tant de persévérance, et de profit pour l'humanité, ainsi que les voeux qu'il forme pour la prosperité de votre Académie.

Veuillez agréer, Monsieur le Président, l'hommage de ma considération très distinguée,

DR. ROUX.

Kansas Academy of Science.

Topeka, Kansas.

Corresponding Secretary of The Academy of Natural Sciences of Philadelphia.

My dear Sir:

Through the Kansas Academy of Science I have the honor of receiving an official appointment as delegate to the One-Hundredth Anniversary of The Academy of Natural Sciences of Philadelphia.

As an old Philadelphian, nothing would give me greater pleasure than to be present at this gathering and to participate in the most worthy celebration. But recent accumulation of work connected with the University has compelled me, very reluctantly, to abandon the idea of personally attending and to forego the pleasure of listening to the various addresses that will be delivered as part of the proposed celebration.

The Kansas Academy of Science extends to the Academy its hearty congratulations. I have the honor to express the wishes of our members that this important occasion will be a delightful and happy one. We trust that the Academy will receive an assurance of even greater support for its future, as its existence has been an inspiration for numerous subordinate organizations in this country. The Academy of Natural Sciences of Philadelphia is looked up to as the Mother-organization.

Sincerely yours

L. E. Sayre,

Dean, School of Pharmacy, University of Kansas,

Representing the Kansas Academy of Science.

KOSMOS GESELLSCHAFT DER NATURFREUNDE STUTTGART.

Am 24. Februar 1912.

The Academy of Natural Sciences of Philadelphia,

Sehr geehrte Herren:

Erlauben Sie uns, Ihnen zu der Hundertjahrfeier vom 19. bis 21. März d. Jhrs. unsern herzlichsten Glückwunsch auszusprechen.

Mit Freuden haben wir das stete Wachsen Ihrer Academy und ihr erfolgreiches Arbeiten, das demselben hohen Zwecke diente, in dessen Dienst auch wir uns gestellt haben, verfolgt.

Wir fügen noch unsern verbindlichsten Dank für Ihre liebenswürdige Einladung bei und bedauern nur, dass die Wasserfläche des Atlantischen Ozeans uns von Ihnen trennt und es uns unmöglich macht, den Festlichkeiten beizuwohnen.

Dass die Academy of Natural Sciences of Philadelphia auch im zweiten Jahrhundert ihres Bestehens weitere schöne Erfolge zu verzeichnen habe, das ist unser Wunsch.

Mit Vorzüglicher Hochachtung
"Kosmos" Gesellschaft der Naturfreunde,
W. KELLER,
E. NEHMANN.

LABORATOIRE MARITIME DE CONCARNEAU, FINISTÈRE.

Concarneau, le 20 Mars 1912.

Monsieur le Président, The Academy of Natural Sciences of Philadelphia.

Cher Monsieur:

J'ai l'honneur de vous adresser tous mes remerciements pour l'aimable invitation que vous avez adressée au Laboratoire de Concarneau à l'occasion du centenaire de la fondation de votre illustre Académie et de vous exprimer en même temps tous mes regrets de ne pouvoir assister, vu la distance qui nous sépare, aux cérémonies qui marqueront cet important événement; mais je me fais un devoir de vous adresser, en meme temps que le témoignage de mon admiration pour les services rendus à la science par votre Institution, l'expression de mes sentiments confraternels et tout dévoués a la cause désinteressée pour laquelle nous travaillons tous, et qui me font vivre aujourd'hui de tout coeur avec vous.

En vous priant, Monsieur le Président, de faire part à tous vos collaborateurs de mes sentiments de très haut estime, je vous prie d'agréer personellement l'expression de mes sincères hommages et de mes distinguées civilités.

Votre entièrement dévoué

DR. F. GUERIN-GANIVET.

LEHIGH UNIVERSITY.

South Bethlehem, Pennsylvania, March 19, 1912.

Lehigh University tenders hearty congratulations to The Academy of Natural Sciences of Philadelphia on the celebration of the One Hundredth Anniversary of the Foundation of the Academy, and all Lehigh men wish long life and increasing success to the Institution that has in this past century of progress done such infinitely great things for the enlightenment and scientific advancement of our people.

By HENRY S. DRINKER,
President,
C. L. THORNBURG,
Secretary.

K. LEOPOLDINISCH-CAROLINISCHE DEUTSCHE AKADEMIE DER NATURFORSCHER.

Der Academy of Natural Sciences of Philadelphia sendet die Kaiserlich Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher zur Feier ihres 100jährigen Bestehens herzlichen Gruss.

Vom 19 bis 21 März dieses Jahres soll der Tag festlich begangen werden, an dem die Academy of Natural Sciences of Philadelphia auf ein Jahrhundert eines ruhmvollen Bestehens zurückblicken kann. Die Kaiserlich Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher nimmt der freudigsten Anteil an diesem Ehrentage der ältesten naturwissenschaftlichen Gesellschaft der Vereinigten Staaten und sendet ihr dazu die herzlichsten Glückwünsche. Seit am 16 April 1812 die sieben Naturforscher G. Troost, N. S. Parmentier, John Shinn, John Speakman. Jacob Gilliams, Thomas Say, und Camillus Mac-Mahon Mann die Akademie begründeten, ist sie ständig emporgeblüht und hat durch ausgezeichnete Mitglieder auf allen Gebieten der Naturwissenschaften: der Ethnologie, der vergleichenden Anatomie und Zoologie, der Botanik, der Paleontologie, Mineralogie und Geologie hervorragendes geleistet. Namen wie Say, Godman, Harlan, Morton, und viele andere, die in JOURNAL und in den PROCEEDINGS der Akademie die Früchte ihrer Forschungen veröffentlichten und ihr Museum und ihre Sammlungen zur höchsten Blüte brachten, werden in der Geschichte der Naturwissenschaften unvergessen bleiben. Möchte die Academy of Natural Sciences of Philadelphia noch viele Jahrhunderte lang bestehen und weiter blühen und gedeihen.

Der Präsident und das Adjunkten-Kollegium der Kaiserlich Leopoldinisch-Carolinischen Deutschen Akademie der Naturforscher.

A. WANGERIN.

Halle a. S. den 19 März 1912.

Finely engrossed.

KIR. MAGYAR TERMÉSZETTUDOMÁNYI TÁRSULAT, BUDAPEST.

VIII, Eszterházy-Utcza 16 Szám. 71/1912.

The President, The Academy of Natural Sciences of Philadelphia.

Sir:

The Royal Hungarian Society of Natural Sciences desires to thank you for the cordial invitation to participate in the festivities on the occasion of the 100th Anniversary of your Academy and regrets that it cannot send representatives to personally express its heartiest congratulations.

Kindly accept the felicitations of our Society for the splendid successes which have attended the efforts of your Academy in the past, and warmest wishes that the Academy may enjoy prosperity in the future.

Yours very truly,

DR. LENGYEL BELA,
President.

MAGYAR TUDOMÁNYOS AKADÉMIA.

To the Corresponding Secretary, The Academy of Natural Sciences of Philadelphia:

The Magyar Tudományos Akadémia feels deeply honoured at the kind invitation extended to it by The Academy of Natural Sciences of Philadelphia to attend the celebration of its Centenary Anniversary, but regrets to say that, owing to the distance and the shortness of the time available, it will be unable to send any delegate to represent it in person at the said celebration.

The Magyar Tudományos Akadémia, however, begs to claim its share in the congratulations offered to your distinguished Academy on the attainment of the first centenary of its existence and to tender its tribute to the splendid services rendered by your Academy to the cause of science and scholarship. This tribute must unfortunately be tendered in writing, owing to the reasons aforesaid, but it is offered in a spirit of the most heartfelt appreciation and esteem for the services your distinguished Academy has rendered to humanity.

The Magyar Tudományos Akadémia begs to couple its tribute of homage and its message of congratulation with the fervent hope that your distinguished Academy may continue for many a century to be such a bulwark of science and scholarship and foremost outpost of human progress as it has been during the past hundred years.

A. BERZEVICZY,
President.

Budapest, 10. March, 1912.

IMP. MOSKOFSKOIE OBSHCHESTVO IESTESTVO-ISPYTATELEI.

Moscou le 20 February, 1912.

To The Academy of Natural Sciences of Philadelphia:

The Imperial Society of Naturalists of Moscow, founded in 1805, has had the pleasure to see the development of The Academy of Natural Sciences of Philadelphia at the beginning to the present time and is able to fix the great success of the Academy during the past hundred years in cultivation of the natural sciences. Our Society very much regrets that the great distance makes it impossible to be represented at the celebration of the Centenary Anniversary of the Academy.

On behalf of the Imperial Society of Naturalists of Moscow, I take the opportunity of offering sincere and hearty congratulations, and of expressing our deep appreciation of the great services that the Academy at Philadelphia has rendered to natural sciences during the last hundred years, and our hope that its activity may long continue in the future.

President:
PROF. DR. N. UMOFF,
Secretaries:
PROF. DR. E. LEYST,
V. DEINEGA.

IMP. MOSKOVSKIJ UNIVERSITET.

Moscow, February 26, 1912.

No. 756.

To The Academy of Natural Sciences of Philadelphia,

Gentlemen:

The oldest of the Russian universities, the Imperial University of Moscow, has directed us, in its behalf, to offer to the oldest of American learned institutions for natural sciences, The Academy of Natural Sciences of Philadelphia, most sincere and hearty congratulations on the auspicious occasion of the Hundredth Anniversary of its scientific birth. In the past hundred years the professors, lecturers, and assistants of our University have followed with great interest the valuable records of the old JOURNAL and the PROCEEDINGS, containing so many memoirs important to natural sciences not only in America, but in all the civilised world. Your PROCEEDINGS are known and valued wherever natural sciences are cultivated.

Much regret is felt that no member of this University can be present as a Delegate at your celebration, to express in terms befitting the occasion the sentiments of high esteem constantly held by us, and the ardent wishes we have for your success in future in every undertaking. We most cordially express confident hope that the future of The Academy of Natural Sciences of Philadelphia will be as brilliant as its past.

Rector
M. LUBAWSKY
Vice-Rector
ERNST LEYST
Pro-Rector
A. ELISTRATOR
Secretary
S. PREOBRASHENSKY.

Muséum National Française d'Histoire Naturelle.

Le Muséum National français d'Histoire Naturelle à l'Académie des Sciences Naturelles de Philadelphie:

L'Assemblée des Professeurs du Muséum national d'Histoire naturelle de France adresse toutes ses félicitations à l'Académie des Sciences Naturelles de Philadelphie à l'occasion de son Centenaire.

La jeune Amérique a su se faire une place d'honneur dans la culture des sciences naturelles; elle s'est signalée par des publications qui comptent parmi les plus belles et les plus importantes, et ses Musées ont pris un développement qui fait l'admiration du Vieux Monde. L'Académie des Sciences Naturelles de Philadelphie a pris la plus grande part à ce mouvement. Elle a toujours été unie par des liens d'étroite sympathie avec le Muséum d'Histoire naturelle, et les Professeurs du vieil établisement trois fois centenaire, héritiers d'un passé glorieux, sont heureux d'offrir leurs vœux à leurs Confrères du Nouveau Monde.

Au nom des Professeurs du Muséum d'Histoire Naturelle de France:

Le Directeur,
Edmund Perrier.

Noms des Professeurs:

Ph. Van Tieghem
A. Chauveau
A. Arnaud
Stanislas Meunier
A. La Croix
L. E. Bouvier
L. Maquenne
J. Costantin
Marcellin Boule
L. Joubin
Louis Mangin
E. Trouessart
H. LeComte
Jean Becquerel
René Verneau
Louis Roule
Louis Lapicque

Folded folio sheet in cover with ornamental border and vignettes, beautifully printed by the Imprimerie Nationale.

's Rijks Museum van Natuurlijke Historie.

Leiden, 17 February, 1912.

The Rijks Museum van Natuurlijke Historie received with the greatest interest the most important information by your Secretary, that your Academy will have completed in March, 1912, one hundred years of active devotion to the cultivation of the Natural Sciences, that for the adequate celebration of its Centenary Anniversary, the Academy will call in convention at its Hall the learned men and institutions of the world—its collaborators, and finally that the Academy invites the Rijks Museum van Natuurlijke Historie to be represented at this event which will take place at Philadelphia on Tuesday, Wednesday, and Thursday, the nineteenth, twentieth, and twenty-first of March, nineteen hundred and twelve.

Now the high scientific rank occupied by your Academy is plain to all students of Nature and we all are impressed by the amount of scientific work done and provided by its members, so pray to accept of the officers of the Rijks Museum van Natuurlijke Historie at Leiden the most hearty congratulations on the great event, and their best wishes for the prosperity of your adult but not old institution!

May in the year 2012 the then living generation state the great fact that your Academy still is flourishing and in the very strong condition that it is now in March, 1912.

It is with the greatest regret that we can not come over to follow the kind invitation with which you honored us; our sincere congratulations may represent us at your Centenary Festival!

Vivat, floreat, crescatque Academia Scientiarum Naturalium Philadelphiensis!

F. A. Jentink,
Directeur van 's Rijks Museum van Natuurlijke Historie.

To the Academy of Natural Sciences of Philadelphia.

Natural History Survey of Minnesota.

The University of Minnesota, Minneapolis, February 28, 1912.

Corresponding Secretary of The Academy of Natural Sciences of Philadelphia.

Dear Sir:

I regret that it will be practically impossible for the Zoological Survey of Minnesota to be represented at the celebration of the Centenary Anniversary of The Academy of Natural Sciences of Philadelphia on March nineteenth, twentieth, and twenty-first, nineteen hundred twelve.

The natural sciences have been and are being advanced by The Academy of Natural Sciences of Philadelphia, and I feel impelled to congratulate in particular the officers of the Academy and the citizens of Philadelphia on the splendid record of the past and wish the Academy continued prosperity in the new century.

Sincerely yours,

Henry F. Nachtrieb,

Zoologist of the Geological and Natural History Survey of Minnesota,
Professor of Animal Biology and Head of the Department.

Naturforschende Gesellschaft in Görlitz.

Görlitz den 18 März 1912.

The Academy of Natural Sciences of Philadelphia:

Die Naturforschende Gesellschaft zu Görlitz hat aus Ihrer freundlichen Einladung mit grossem Interesse ersehen, dass auch Sie in diesem Jahre auf ein hundertjahriges Wirken im Interesse unserer Naturwissenschaften zurückblicken.

Indem wir für die freundliche Einladung zu diesem Feste, an dem wir uns leider durch kein Mitglied vertreten lassen können, danken, wünschen wir Ihnen viel Glück und Gedeihen für die Zukunft.

Im Namen des Präsidiums

Dr. Willy Meyer,
I. Sekretär.

NATURHISTORISCHE GESELLSCHAFT NÜRNBERG.

Nürnberg, den 7 März 1912.

An die Academy of Natural Sciences of Philadelphia:

Die Naturhistorische Gesellschaft Nürnberg entbietet der Academy of Natural Sciences zu ihrer Jahrhundertfeier die allerherzlichsten Glückwünsche. Die verflossenen hundert Jahre waren für die Entwicklung der Naturwissenschaften ungemein segensreich und fruchtbringend; die Academy hat durch die Arbeiten ihrer Gelehrten in hohem Masse dazu beigetragen, die Erfahrungen der Wissenschaft in weite Kreise zu tragen. Seit 56 Jahren stehen unsere beiden Institute in wechselseitigem Verkehr. Möge der rege Austausch der geistigen Kulturgüter, alte und neue Welt eng und freundschaftlich aneinander knüpfend, auch in Zukunft das gleiche erhebende Bild zeigen, das die Vergangenheit ausgezeichnet hat.

Für die Naturhistorische Gesellschaft, Nürnberg

I. Sekretär

PROFESSOR DR. KÜSPERT.

K. K. NATURHISTORISCHES HOFMUSEUM, WIEN.

K. und K. Intendanz des K. K. Naturhistorischen
Hofmuseums, Wien, 27. Februar 1912.

The Academy of Natural Sciences of Philadelphia:

Der ergebenst Gefertigte erlaubt sich, der hochansehnlichen Akademie der Naturwissenschaften anlässlich der Feier Ihres Einhundertjährigen Bestandes im Namen des k. k. naturhistorischen Hofmuseums in Wien die herzlichsten und ergebensten Glückwünsche darzubringen.

Mit gerechtem Stolze und voller Befriedigung kann die hohe Akademie auf ihre Einhundertjährige erfolgreiche Tätigkeit auf dem weiten Gebiete der Naturwissenschaften zurückblicken. Zu Ihren Gründern und Mitarbeitern zählen ja die grössten amerikanischen Gelehrten des vergangenen Jahrhunderts, deren Namen unsterblich fortlebt in der Geschichte der Naturwissenschaften.

Möge es der hohen Akademie in Philadelphia gegönnt sein, noch viele Jahrhunderte in gleicher segensreicher Weise zu wirken zum Ruhme Ihres grossen Vaterlandes und zur Förderung des Wissens der gesammten gebildeten Welt.

"Vivat, floreat, crescat Academia."

Die Intendanz des k. k. naturhistorischen Hofmuseums bedauert sehr, wegen der Grösse der Entfernung und der ungünstigen Jahreszeit keinen Delegierten nach Philadelphia zu dieser seltenen, erhebenden Feier entsenden zu können.

DR. FRANZ STEINDACHNER,
Intendant des k. k. naturhistorischen Hofmuseums.

NATURHISTORISCHES MUSEUM ZU HAMBURG.

Der Academy of Natural Sciences of Philadelphia, der hochverdienten Pflegerin und Förderin wissenschaftlicher Forschung, sendet zur Feier ihres hundert-jährigen Bestehens herzlichsten Glückwunsch.

Das Naturhistorische Museum zu Hamburg,

KRAEPELIN.

Hamburg, den 20 Februar 1912.

A fine specimen of chirography.

NATURHISTORISCH-MEDIZINISCHER VEREIN HEIDELBERG.

Heidelberg d. 1 März 1912.

An die Academy of Natural Sciences of Philadelphia:

Der Naturhistorisch-medizinische Verein zu Heidelberg bedauert ausserordentlich keinen Vertreter zu Ihrem Feste entsenden zu können; aber er beauftragt mich Ihnen seine herzlichsten Glückwünsche zu übermitteln. Er kennt wohl die Bedeutung, welche Ihre ausgezeichnete Academy für die Ausbreitung und Entwicklung naturwissenschaftlicher Kenntniss in den Vereinigten Staaten gehabt hat; er beglückwünscht Sie zu Ihren grossen Erfolgen und wünscht, dass Sie auch im zweiten Jahrhundert nicht weniger segensreich werden mögen.
In ausgezeichneter Hochachtung und Verehrung

der Schriftführer
PROF. DR. WILHELM SALOMON.

DEN NATURHISTORISKE FORENING: KÖBENHAVN.

Feb. 28, 1912.

To the Corresponding Secretary of The Academy of Natural Sciences of Philadelphia.

Sir:

On behalf of the Naturhistoriske Forening i Köbenhavn, I wish to express our best thanks for the great honour of being invited to be represented at the celebration of the Centenary of The Academy of Natural Sciences of Philadelphia.

We deeply regret not to be able to send a delegate at this event; we must confine ourselves to sending our most hearty congratulations on the completion of the first hundred years of successful work in promoting science, and to express the hope that the Academy may continue to grow and flourish for ages to come.

Believe me, Sir,
Yours respectfully,
HECTOR F. E. JUNGERSEN,
President of Naturhistorisk Forening.

NATURWISSENSCHAFTLICHER VEREIN, HAMBURG.

Der Academy of Natural Sciences zu Philadelphia sendet der naturwissenschaftliche Verein in Hamburg in freudiger Anerkennung der Verdienste der Akademie um die Förderung der Naturwissenschaften zu der Feier ihres hundertjährigen Bestehens am 19, 20, und 21 März 1912 seinen aufrichtigsten Glückwunsch.

Der derzeitige 1. Vorsitzende
PROF. DR. G. GÜRICH.

Folded sheet in cover with seal of society.

NATURWISSENSCHAFTLICHER VEREIN FÜR SCHLESWIG-HOLSTEIN.

An die Akademie der Naturwissenschaften in Philadelphia

Hochgeehrte Herren:

Zu der bevorstehenden Feier Ihres 100 jährigen Bestehens beehren wir uns die herzlichsten Glückwünsche zu übersenden.

Wenn wir uns es auch versagen müssen, der freundlichst an uns ergangenen Einladung durch Entsendung eines Vertreters zu entsprechen, so wissen wir uns doch eins mit Ihnen in der Freude über die bedeutsamen Erfolge Ihres Wirkens und in der Wertschätzung derjenigen Bedeutung, welche innerhalb der gesammten Cultur der Pflege naturwissenschaftlicher Kenntnisse zukommt.

Wir wünschen und hoffen, dass dem Ruhmeskranze, den sich Ihre Akademie durch ernste und fruchtbare hundertjährige Arbeit verdient hat, ungezählte neue Blätter fernerhin hinzugefügt werden.

HENSEN,
L. WEBER.

Kiel, den 10 März 1912.

Naturwissenschaftlicher Verein für Steiermark in Graz.

To the Corresponding Secretary, The Academy of Natural Sciences of Philadelphia:

Der Naturwissenschaftliche Verein für Steiermark dankt Ihrer Academy für die freundliche Einladung zum hundertjährigen Jubiläum ihrer Gründung.

Durch ein Jahrhundert an der Spitze aller der seither in Amerika entstandenen jüngeren gelehrten Gesellschaften stehend, welche sich die naturwissenschaftliche Erforschung Ihres grossen und mächtigen Vaterlandes zur Aufgabe machten, hat die Academy of Natural Sciences of Philadelphia in dieser für die Wissenschaft kurzen Zeit Erfolge erzielt, die mit Recht die Bewunderung der gelehrten Welt erregten. Unser Naturwissenschaftlicher Verein, dem Sie die Ehre erwiesen, ihn zu Ihrer Feier einzuladen, sendet Ihnen die herzlichsten Glückwünsche für ein gleich ruhmreiches Wirken in vielen weiteren Jahrhunderten.

Nederlandsche Dierkundige Vereeniging.

To The Academy of Natural Sciences of Philadelphia:

The Nederlandsche Dierkundige Vereeniging has the honour to acknowledge the receipt of the kind invitation from The Academy of Natural Sciences of Philadelphia, to be represented at the celebration of its Centenary Anniversary.

The Vereeniging regrets to be obliged to inform the Academy that it will not be able to attend this no doubt very successful meeting.

It therefore forwards by way of this letter its best wishes for the flourishing of the institution, that has already done so exceedingly much for the advancement of the Natural Sciences.

May the Academy in future be able to carry on this noble task with juvenile strength!

P. P. C. Hoek,
President,
R. Horst,
Secretary.

$\frac{\text{Haarlem}}{\text{Leiden}}$, 21st February, 1912.

NEDERLANDSCHE ENTOMOLOGISCHE VEREENIGING.

Rotterdam, the 7th of February, 1912.

To The Academy of Natural Sciences of Philadelphia.

Dear Sirs:

Our Society, though greatly honoured by your kind invitation to send a representative to the celebration of the Centenary Anniversary of your Academy, regrets much to be unable to accept it, as the travel to Philadelphia is too far.

The Board of our Society takes the liberty to offer you the best wishes for the future prosperity of your Academy and hopes that it will be able to continue with the same devotion and success the scientific labor, which is highly appreciated also by the members of our Society.

I remain, Dear Sirs,

Yours faithfully,

D. VAN DER HOOP,
Secretary.

NEW YORK ACADEMY OF SCIENCES.

The New York Academy of Sciences sends most hearty greetings to The Academy of Natural Sciences of Philadelphia on the occasion of the latter's celebration of the One Hundredth Anniversary of her founding.

Next younger in age among such institutions in the country, the New York Academy feels an especial right to congratulate her sister Academy upon rounding out the first century of an existence that has been honorable for work accomplished along several lines, but particularly in conchology and geology. Now that there are so many centers of scientific work and thought in America there is danger of overlooking the claims to recognition of the great original source of inspiration. May Philadelphia maintain for centuries to come the front rank in this regard that has been hers for more than the century now closing.

EMERSON MCMILLAN,
President.
EDMUND OTIS HOVEY,
Recording Secretary.

Beautifully engrossed on parchment with illuminated initials.

Northwestern University, Evanston-Chicago.

Northwestern University offers congratulations to The Academy of Natural Sciences of Philadelphia on the arrival of its One Hundredth Anniversary, and takes pleasure in paying a tribute to its helpful and uplifting influence on the progress of the natural sciences.

Through its museum exhibits and public lectures, as well as through the personal influence of its distinguished members, the Academy has promoted a widespread interest in the natural sciences. At the same time, it has stimulated research by providing means of publication for many notable scientific investigations that have been produced by its members and correspondents.

This activity establishes between the Academy and the Universities a bond of sympathy, based on similarity of aims and purposes in promoting the spread of education among the people, and in offering encouragement to gifted investigators.

In recognition of this high service to the cause of scientific learning, Northwestern University not only offers felicitations for past achievements, but also wishes for The Academy of Natural Sciences of Philadelphia continued prosperity and success in the prosecution of its noble work.

Chicago, Illinois, March fifteenth, nineteen hundred and twelve.

A. W. Harris,
President.

PHILADELPHIA COLLEGE OF PHARMACY.

145 North 10th St., Philadelphia, March 14, 1912.

Samuel G. Dixon, M.D., President, The Academy of Natural Sciences of Philadelphia.

Dear Sir:

The Philadelphia College of Pharmacy, which is approaching its Ninety-second Anniversary, desires to extend to your Academy her heartiest greetings upon this felicitous occasion of its Centenary Anniversary.

The College recalls with pride the fact that the first President of your Organization, Gerard Troost, M.D., a man highly esteemed by all, afterwards became associated with her as Professor of Chemistry.

The Academy of Natural Sciences of Philadelphia and the Philadelphia College of Pharmacy have been so closely allied during the lifetime of the latter, that she feels it a great honor to have this opportunity of extending to the older sister institution her heartiest good wishes for a continuance of such an honored career. And it is her hope that the most excellent work which the Academy has so nobly and heroically carried on during the past one hundred years may continue through future centuries.

Very truly,

Attest: HOWARD B. FRENCH,
President.

C. A. WEIDEMANN, M.D.,
Secretary.

The Philadelphia Pathological Society.

To The Academy of Natural Sciences of Philadelphia, 1812–1912, Greeting!

The Philadelphia Pathological Society extends to The Academy of Natural Sciences cordial greetings upon the completion of one hundred years of active, productive life, congratulating the Academy upon its notable record of past achievements, and earnestly wishing for it long continuance of life, prosperity and success.

By Delegates: Allen J. Smith,
President,
David Riesman,
Past President,
W. M. L. Coplin,
Past President.

Philadelphia, Pa., March 19, 1912.
Beautifully engrossed.

Philadelphia High School for Girls.

Greetings of the Philadelphia High School for Girls to The Academy of Natural Sciences of Philadelphia (1812, March 21, 1912).

All institutions whose object is the pursuit of exact knowledge rejoice with The Academy of Natural Sciences of Philadelphia on this the celebration of the One hundredth Anniversary of its foundation.

The Philadelphia High School for Girls is glad at this time to extend its sincere congratulations and to have the opportunity of expressing its deep sense of obligation to the Academy. Situated as the school is, almost in the shadow of the walls of this famous institution, it has found the Academy a helpful neighbor. Teachers and pupils have derived inspiration from its unique collections, from the clear and comprehensive lectures arranged to meet the special interests of the school, and from the willing aid received many times in the effort to solve difficult problems connected with the work.

May the Academy of Natural Sciences of Philadelphia flourish in the future as it has in the past, may it continue in its honest devotion to the development of science, in its attainment of end for the betterment of mankind, in its world-wide reputation for members of sterling qualities and of great achievement.

J. Eugene Baker,
Principal,
Katherine E. Pinncheon,
Assistant to Principal,
Ida A. Keller,
Head of Department of Biology.

PONTIFICIA ACCADEMIA ROMANA DEI NUOVI LINCEI, ROMA.

Palazzo della Cancelleria, Roma, 13 Febbraio, 1912.

Monsieur le Président:

J'ai l'honneur de vous exprimer au nom de l'Académie Pontificale des "Nuovi Lincei" les sentiments de la plus vive et fraternelle sympathie pour votre honorable Academy of Natural Sciences of Philadelphia à l'occasion des fêtes centenaires qui auront lieu le mois prochain à Philadelphie.

Nous souhaitons à votre glorieuse Institution un avenir digne du passé, pour le plus grand avantage des sciences que vous cultivez si noblement, et dont vous vous intéressez si largement du progrès.

Nous formons en même temps les voeux les plus sincères pour la prospérité de tous les Académiciens.

Veuillez agréer, Monsieur le Président, l'expression de ma haute considération.

DR. PIERRE DE SANCTIS,
Secretaire.

M. le Président de la Academy of Natural Sciences of Philadelphia.

Die Physikalisch-oekonomische Gesellschaft zu Königsberg i. Pr.

Königsberg i. Pr., 6 März 1912.

An der Centenarfeier der Academy of Natural Sciences of Philadelphia nimmt die Physikalisch-oekonomische Gesellschaft zu Königsberg i. Pr. der es leider nicht möglich ist, einen Vertreter über den Ocean zu entsenden, herzlichen Anteil und erlaubt sich, wenigstens schriftlich ihre besten Glückwünsche darzubringen.

Wer die mit 1817 beginnende Reihe der Veröffentlichungen der Akademie einsieht, stösst auf eine stattliche Zahl über Amerika hinaus bekannt gewordener Namen, deren Arbeiten einen dauernden Gewinn für die Wissenschaft darstellen. Wie aber zu einem Gebäude ausser den Grund- und Eckpfeilern viele grössere und kleinere Bausteine notwendig sind und ohne solche ein Bau nicht errichtet werden kann, so verhält es sich auch mit der Wissenschaft, die ohne oft minutiöse Detailarbeit nicht bestehen kann. Auch hieran hat es der Academy nicht gefehlt, und so bilden ihre bisherigen Leistungen das beste Prognosticon für die Zukunft.

Die Physikalisch-oekonomische Gesellschaft
Der Schriftführer
M. Lühe
Der Präsident
M. Braun.

Roemer Museum.

Hildesheim, den 15. 2. 12.

Sehr geehrter Herr:

Für die liebenswürdige Einladung zu dem Hundertjährigen Stiftungsfeste der Academy of Natural Sciences of Philadelphia sagt der Vorstand des Roemer-Museums ehrerbietig seinen Dank. Leider ist er nicht in der Lage einen Delegierten zu senden, um seine herzlichen Glückwünsche zu überbringen. Er hat mich beauftragt, diese Glückwünsche hiermit Ihnen aus vollem Herzen darzubringen:

Vivat! Floreat! Crescat! Academia Scientiæ Naturalis Philadelphiæ!
In æterum!

Mit ausgezeichneter Hochachtung
Prof. Dr. R. Hauthal.

Royal Society of Edinburgh.

To The Academy of Natural Sciences of Philadelphia:

The Royal Society of Edinburgh takes with great pleasure the opportunity of expressing to The Academy of Natural Sciences of Philadelphia, its congratulations upon the celebration of the Academy's Centenary.

Sharing as it does the proud duty of advancing and diffusing knowledge, the Society recognises the debt due to those who, under the aegis of the Academy, have so zealously and so successfully laboured with the same end in view, to the benefit not of one country only but of mankind.

The Society feels it a peculiar pleasure to convey upon so auspicious an occasion, by the hands of its personal representatives, these sincere congratulations to an Academy of a country with which Scotland has had such long and intimate connections, and with cordial greetings expresses its confident hope for a continuance of the Academy's distinguished career.

(*Seal*)

Wm. Turner,
President,
C. G. Knott,
Secretary.

Edinburgh, March, 1912.

Beautifully printed on folio sheet

RUSSKOJE ENTOMOLOGIČESKOJE OBŠČESTVO.

To the President, The Academy of Natural Sciences of Philadelphia.

On the occasion of the Centennial Jubilee Celebration of The Academy of Natural Sciences of Philadelphia the Russian Entomological Society welcomes the remembrance that the Academy has always paid much attention to entomology.

In order to appreciate the enormous significance of the part the Academy has played in the study of the branch of zoology which is so dear to our Entomological Society, it is sufficient to quote the names of the following famous savants, whose works appeared in the publications of the Academy: B. Clemens, E. T. Cresson, S. S. Haldeman, N. M. Hentz, G. H. Horn, J. Leconte, J. L. Leconte, F. E. Melsheimer, Miss M. Morris, W. F. Rogers, Baron R. Von Osten-Sacken, Th. Say, Ph. R. Uhler, D. Ziegler, and many others.

The Russian Entomological Society presents its heartiest congratulations on the Centennial Anniversary of The Academy of Natural Sciences of Philadelphia and wishes that it may continue in future its useful work and to flourish for many years to come.

P. SEMENOV-TJAN-SHANSKIJ,
President.
ANDREA SEMENOV-TJAN-SHANSKIJ,
Vice President.
G. JACOBSON,
Secretary.
O. JOHN,
Corresponding Secretary.

K. Sächsische Gesellschaft der Wissenschaften.

Leipzig, den 8 März 1912.

The Academy of Natural Sciences of Philadelphia:

Der Academy of Natural Sciences of Philadelphia spreche ich meinen warmen und ehrerbietigen Dank für die Einladung zur Teilnahme an der Feier des 100-jährigen Bestehens aus.

Wenn ich auch nicht in der Lage bin, persönlich an der Feier teilzunehmen, so möchte ich doch nicht verfehlen, der Akademie meinen aufrichtigen Glückwunsch darzubringen, und die Hoffnung auszusprechen, dass von ihr auch weiterhin segensreiche wissenschaftliche Anregungen ausgehen möchten.

Wenn ich an mein Spezialgebiet, die Zoologie, denke, so darf ich wohl darauf hinweisen, dass der 1817 erschienene erste Band des Journal of the Academy of Natural Sciences of Philadelphia eine Reihe ausgezeichneter zoologischer Abhandlungen enthält, von denen die erste keinen geringeren als LeSueur zum Verfasser hat.

Seit jener Zeit hat die Akademie eine solche Fülle ausgezeichneter Untersuchungen und hervorragender Entdeckungen auf dem Gebiete der beschreibenden Naturwissenschaften veröffentlicht, dass sie schon lange einen Ehrenplatz unter den wissenschaftlichen Vereinigungen der neuen und alten Welt einnimmt.

Vivat, crescat, floreat!

Der Sekretär der mathem.-physischen Klasse:

Carl Chun.

K. Sächsische Gesellschaft der Wissenschaften.

Leipzig, den 9. März 1912.

Die Königlich Sächsische Gesellschaft der Wissenschaften spricht der Academy of Natural Sciences of Philadelphia ihren warmen Glückwunsch aus Anlass der 100jährigen Jubelfeier aus.

Unter den wissenschaftlichen Vereinigungen Amerikas ist sie nicht nur eine der ältesten, sondern auch bis heute eine der angesehensten, deren segensreiche Tätigkeit auf das geistige Leben der Vereinigten Staaten und des Auslandes einen deutlich erkennbaren Einfluss ausübte. Durchmustert man die Liste ihrer Mitglieder, so findet man in ihr die stolzesten Namen amerikanischer Gelehrter: begreiflich, dass man im Auslande es sich zur besonderen Ehre anrechnete, zu der Academy of Natural Sciences of Philadelphia persönliche Beziehungen zu gewinnen.

Seit dem Jahre 1817, in dem der erste Band des Journal of the Academy of Natural Sciences of Philadelphia erschien, hat die Akademie eine solche Fülle bedeutsamer Arbeiten und Entdeckungen veröffentlicht, dass ihre Publikation an innerem Gehalt mit den ehrwürdigsten Zeitschriften der alten Welt wetteifern kann. Ihr Leitmotiv waren die Worte von Montagu: "By withholding individual information general knowledge is suspended. Science is materially advanced by the promulgation of the sentiments of individuals, and poor indeed must be the resources of those from whom nothing is to be learned."

So erkennen wir denn mit der gesamten wissenschaftlichen Welt dankbar an, dass der vor 100 Jahren in bescheidener Form gepflanzte Baum wissenschaftlicher Erkenntnis herrliche Früchte getragen hat, und wünschen der Academy of Natural Sciences of Philadelphia auch weiterhin ein segensreiches Gedeihen.

Die Königl. Sächs. Gesellschaft d. Wissenschaften.

Der Sekretar d. mathem.-phys. Klasse:
Carl Chun

Der Sekretar d. phil.-hist. Klasse:
Ernst Windisch.

Schweizerische Naturforschende Gesellschaft.

Genève, le 13 Mars 1912.

La Société Helvétique des Sciences Naturelles à The Academy of Natural Sciences of Philadelphia.

Monsieur le Président et très Honoré Confrère:

Par suite d'une erreur de l'Administration des Postes, l'invitation que vous nous avez fait l'honneur de nous adresser pour nous faire représenter aux belles cérémonies par lesquelles vous célébrez le Centenaire de votre savante société, nous parvient trop tard pour que nous puissions y prendre part.

Nous tenons néanmoins à venir vous exprimer les sentiments de vive admiration que nous éprouvons à la pensée que votre savante Compagnie puisse célébrer cette année, le centième anniversaire de sa fondation, et nous venons vous prier d'agréer tous les voeux les plus sincères que nous formons pour sa prospérité dans le second siècle d'activité qui s'ouvre devant elle.

Veuillez agréer, Monsieur le Président et très Honoré Confrère, l'assurance de notre considération la plus distinguée.

Pour Le Comité Central
Le Président
Ed. Sarasin
La Secrétaire
Ph. A. Guye.

Smithsonian Institution.

The Smithsonian Institution sends greetings and congratulations to The Academy of Natural Sciences of Philadelphia on the occasion of the One hundredth Anniversary of its Foundation.

Recognizing the importance of the influence which, for a century, the Academy has exerted on the development of American science and the value of the contributions which it has made to natural history, the Institution desires to express the hope that its beneficent activities may long continue.

Charles Walcott,
Secretary.

March the Nineteenth, One Thousand Nine Hundred and Twelve.
Exquisitely engrossed and illuminated.

La Sociedad Aragonesa de Ciencias Naturales.

La Sociedad Aragonesa de Ciencias Naturales en el primer decenio de su existencia se congratula con la Academia de Ciencias Naturales de Filadelphia en su Centenario 1812–1912.

Seculari Academiæ Scientiarum Philadelphianæ Gratulatio.

Ferte, leves venti, mea munera, ferte salutem
Ad Philadelphinos fluctibus oceani.
En celebrat primum sapiens Academia seclum.
Gaude, dumque volent tempora progredere.

Colegio de Salvador
Cæsarangustæ, Febr. 1912.

Longin Navás, S.J.

Sociedad Malaguena de Ciencias.

Malaga, Febrero 1912.

The Secretary the Academy of Natural Sciences of Philadelphia:

La Sociedad Malagueña de Ciencias tributa á su homóloga de Philadelphia felicitación entusiasta al conmemorar ésta su primer Centenario de brillante existencia.

Nos honrariamos concurriendo al certamen que vais á celebrar con tan fausto motiva, mas ya que ello no nos sea posible, recibid nuestro saludo sincero y nuestros fervientes votos por vuestra prosperidad creciente para bien de la Ciencia y de la Humanidad.

Al trasmitiros estos acuerdos os damos expresivas gracias por vuestra invitación y nos ofrecemos vuestros afectuosos colegas.

El Secretario,
El Presidente,
Z. Rodriques Spiteri.

SOCIETÀ DEI NATURALISTI E MATEMATICI IN MODENA.

Modena, 28 Febbrajo 1912.

The Academy of Natural Sciences of Philadelphia:

Un secolo di vita scientifica hanno dato alla Vostra Accademia tutto lo splendore che molte delle vostre Consorelle hanno raggiunto durante un tempo più che doppiamente secolare; e accanto a Voi e per la vostra influenza esercitata in mezzo alle attive e giovani popolazioni dell'America del Nord, vi sono cresciuti attorno sodalizi e istituzioni scientifiche largamente fruttuose.

È con la più sentita gioja intelletuale che noi prendiamo parte alle vostre feste giubilari; il tempo e anche la distanza non permettono alla Società dei Naturalisti e Matematici di Modena di inviare un rappresentante alle vostre adunanze solenni; ma lontani, saremo con Voi in quei giorni con l'animo nostro, e vi auguriamo, non senza un certo egoismo scientifico che ormai i lavori dei singoli sulla terra sono a benefizio di tutti, una indefettibile vita per la grandezza del vostro Paese, per il benessere dell'umanità.

il Presidente
DANTE PANTANELLI
il Segretario
GIACOMO G. BASSOLI.

SOCIETÀ ZOOGICAL ITALIANA.

Roma, li 23 Febbraio, 1912.

Illmo Signor Presidente:

Riceviamo con piacere il cortese annunzio della prossima celebrazione del Centenario di codesta illustre e benemerita Accademia scientifica. Dispiacenti di non poter intervenire personalmente alla festa commemorativa, Vi preghiamo, illustrissimo Signor Presidente, di voler rappresentare la nostra Società Zoologica Italiana. Vogliate accettare, da parte di tutti i membri di questa Società, i più caldi e sinceri augurî affinchè il vostro Istituto possa continuare per l'avvenire nel suo nobile compito, così degnamente e felicemente adempito finora, di giovare al progresso delle scienze naturali, che è anche progresso della civiltà dei popoli.

Con devozione e stima
Il Presidente
PROF. ANTONIO CARRUCCIO
Il Segretario
PROF. GIUSEPPE LEPRI

All' ill. Sig. Presidente dell'Accademia di Scienze Naturali in Filadelfia.

Regia Societas Scientiarum Bohemica.

Prag am 5 März 1912.

An die Academy of Natural Sciences of Philadelphia:

Die Königlich Böhmische Gesellschaft der Wissenschaften in Prag hat mit innigstem Dank die Einladung zu Festtagen empfangen, an welchen die Academy of Natural Sciences ihr hundertjähriges Bestehen zu feiern gedenkt, bedauert jedoch, dass es ihr nicht möglich ist, ihren Vertreter zur Feier selbst entsenden zu können.

Die Gesellschaft schliesst sich jedoch mit Freuden allen jenen an, die nah und fern in diesen Tagen des ruhmreichen, dem Fortschritte der Wissenschaft gewidmeten hundertjährigen Wirkens der Academy mit Dank gedenken und entbietet der Academy ihre schlichten, aber aufrichtigen Worte der Bewunderung für all die bisher der Wissenschaft geleisteten Dienste und die besten Glückwünsche für ihre Fortsetzung in den kommenden Jahrhunderten. Academia scientiarum naturalium Philadelphiensis vivat, floreat, crescat!

Für das Präsidium der Königlich Böhmischen Gesellschaft der Wissenschaften

K. Vrba
Präsident,
Josef Zubaty
General-Sekretär.

Société Botanique de France.

Rue de Grenelle, 84, à Paris (VII.e) Paris, le 4 Mars 1912.

A Monsieur le Président et à Messieurs les Membres de l'Académie des Sciences naturelles de Philadelphie:

Messieurs:

Au moment où votre savante Académie célèbre le 100e anniversaire de sa fondation, la Société Botanique de France tient à vous exprimer ses plus vives félicitations.

Vos importants travaux ont assuré à l'Académie des Sciences naturelles de Philadelphie une place d'honneur parmi les sociétés savantes d'Amérique.

Nous formons le voeu que votre activité scientifique, toujours en éveil, continue à enrichir l'histoire naturelle d'importantes découvertes qui contribueront heureusement à illustrer à la fois, votre Académie et la science américaine.

Le Président de la Société Botanique de France,
R. Zeiller.

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES.

Los Angeles.

The Southern California Academy of Science gratefully acknowledges the invitation to attend the celebration of the One-hundredth year of the establishment of The Academy of Natural Sciences of Philadelphia.

We extend to The Academy of Natural Sciences of Philadelphia our most hearty congratulations for its phenomenal success, and for the many discoveries in the several branches of science which have been made through its encouragement and liberality, and which have tended to the advancement of the human race during the last one hundred years.

We, upon this distant Pacific Coast, a very young sister Academy, born but twenty-one years ago, are glad to be able to place upon record, at this auspicious event, our appreciation of the work of The Academy of Natural Sciences of Philadelphia and the good that has resulted from its labors.

W. A. SPALDING,
President.
HOLDRIDGE O. COLLINS,
Secretary.

STATE OF CALIFORNIA
COUNTY OF LOS ANGELES } ss.

I, Holdridge Ozro Collins, Secretary of the Southern California Academy of Sciences, do hereby certify that at the regular meeting of said Academy, held in the City of Los Angeles, County and State aforesaid, on the 29th day of February, 1912, the foregoing Memorial was unanimously adopted.

WITNESS my hand and the Seal of said Academy at said City of Los Angeles, this fourth day of March, 1912.

HOLDRIDGE OZRO COLLINS,
Secretary.

STOCKHOLMS HÖGSKOLA.

To the President of The Academy of Natural Sciences of Philadelphia:

The University of Stockholm—Stockholm's Högskola—wishes to send to The Academy of Natural Sciences of Philadelphia on its Centenary Anniversary, the most hearty congratulations on the admirable evolution of Natural Science in North America, which has taken place during the past seculum, and in which your Academy has taken such an active part.

Having unfortunately no opportunity of accepting your kind invitation to send a representative, we must confine ourselves to send you in this way our very best wishes.

On behalf of the Senate of the University of Stockholm,
IVAR BENDIXSON.

Stockholm 11/3/1912.

SVENSKA SÄLLSKAPET FOR ANTROPOLOGI OCH GEOGRAFI.

To The Academy of Natural Sciences of Philadelphia:

The Swedish Anthropological and Geographical Society begs to acknowledge the receipt of your invitation to the Centenary Celebration of the founding of your Academy.

We very heartily rejoice at the occasion for congratulating your Academy, the oldest institution of its kind in America for the pursuit of natural history researches. We send this message to you with all the more eagerness and ardour from the circumstance that your society originated and has flourished in a district of America where fellow-countrymen of ours of an earlier day were among those who first sowed the seeds of civilization.

EMIL EKHOFF.

J. G. ANDERSSON	E. W. DAHLGREN	GERARD DEGEER
E. NORDENSKIÖLD	EDW. JÄDERIN	AXEL LAGRELIUS
OSCAR MONTELIUS	A. G. NATHORST	SVEN HEDIN
LOUIS PALANDER	BERNHARD SALIN	HENRIK SANTESSON

AXEL WALLÉN GUNNAR ANDERSSON.

Stockholm, February 22, 1912.

In a beautiful blue crushed levant ornamented portfolio.

K. Svenska Vetenskapsakademien.

To The Academy of Natural Sciences of Philadelphia:

On the occasion of your esteemed Academy celebrating the One Hundredth Anniversary of her existence, the Royal Swedish Academy of Sciences desires to join the various other scientific societies both in the New World and the Old, who just now direct their congratulation to you.

The connection of scientific interests which exists between your country and our own dates back into the past. Peter Kalm, a pupil of the great Linnæus and a member of our Academy, devoted his researches to the virgin fields, which the people of the United States have converted into one of the world's richest civilized countries. Our published transactions and our archives contain many contributions giving us information concerning the natural productions and conditions of America. Among the thousands of emigrants which our country send you, not a few have made themselves known as scientific students and have thus in their adopted country done credit to the education they have received in the homeland.

The work of American scientists has, here in Sweden, always been studied and appreciated, and has had a most beneficial effect on Swedish scientific work.

For the part your Academy has taken in our efforts we, therefore, desire to express our gratitude, and to wish you continued success in the great field of natural science from which modern culture has reaped such rich harvests.

E. W. Dahlgren,
President.

Chr. Aurivillius,
Secretary.

Stockholm, 28th February, 1912.
Superbly printed on folio sheet.

Tsentralnaia Fizicheskaia Observatoria Nicolas.

To The Academy of Natural Sciences of Philadelphia:

The Central Physical Observatory of Nicolas at St. Petersburg begs The Academy of Natural Sciences of Philadelphia to accept the sincerest congratulations of the Observatory on the occasion of the completion of one hundred years of most active devotion to the cultivation of the natural sciences, one branch of which forms the task of the Observatory.

We wish most heartily that the Academy, the oldest institution of the United States for the study of the natural sciences, which has so much contributed to the progress of these sciences, may in the next centuries of activity continue its work with the same success.

Director:
M. Rykatchew
Vice Director:
Ed. Stelling
Scientific Secretary:
E. Heintz.

St. Petersburg, 19 March, 1912.

Tokyo Geographical Society.

Tokyo, March 9th, 1912.

The Academy of Natural Sciences of Philadelphia:

We return our hearty thanks for your kind letter, inviting us to send a delegate to attend the glorious celebration of the Centenary Anniversary of your Academy. Your Academy, born as it was in the days when Geography was in its cradle, has ever since rendered great services to the progress of the natural sciences in the world. As the celebration assumes the double importance on that account, we should feel very anxious to be present at the celebration if we could. We, however, greatly regret to have to inform that various circumstances hinder us from sending you a delegate of our own.

Again with many thanks for your kind invitation and with our heartfelt wishes that the celebration will prove a great success,

We have the honour to remain, Sir,

Kinosuke Inouye,
General Secretary.

R. Università degli Studi, Bologna.

Universitas Litterarum et Artium Bononiensis Academiæ Disciplinarum Naturalium quæ abhine Annos C Philadelphiæ condita est, in urbe præclara cuius ipsum nomen et gentes hominum et doctrinas de sororio vinculo monere videtur, modo felicem illum natalem est rite celebratura de expletis ante muneribus partaque laude gratulatur, uberrimos industriæ fructus in posterum exoptat.

Leo Pesci
Rector Universitatis.

X. Kal. Mart. MCMXII.
Superbly engrossed and decorated on folio parchment sheet.

Università di Torino.

Torino, Addì I Marzo, 1912.

Illmo Signor Presidente:

Ho ricevuto il gentile invito da cotesta Accademia di Scienze naturali rivolto alla nostra Università di farsi rappresentare alle Feste che avranno luogo prossimamente in Filadelfia nella ricorrenza del Centenario della fondazione della Accademia stessa.

A nome anche del corpo insegnante di questo Ateneo, che ho l'onore di presiedere, ringrazio vivamente per così delicato pensiero la gloriosa Accademia di Filadelfia, la quale, assai apprezzata anche in Italia, giustamente si propone di celebrare, con la maggiore solemnità, la sua secolare esistenza, tuta dedicata al progresso delle Scienze Naturali.

Ma poiché, per la grande distanza, non sarà possibile inviare uno speciale delegato, prego la cortesia della S. V. Illma di voler rappresentare a tali Feste la R. Università di Torino.

Con il maggiore ossesquio

Il Rettore
N. Ruffini

All' Illmo Signor Presidente dell'Accademia di Scienze Naturali Filadelfia.

UNIVERSITÄT HEIDELBERG.

Heidelberg, den 7, März 1912.

Für die freundliche Einladung zu Ihrer Jubelfeier sagen wir herzlichen Dank. Es ist uns zu unsrem lebhaften Bedauern nicht möglich, einen Vertreter unsrer Hochschule zur Ueberbringung unsrer Glückwünsche zu entsenden. So entbietet die älteste Universität des Deutschen Reiches, die Ruperto-Carola, der altehrwürdigen Akademie der Naturwissenschaften zur Feier des hundertjährigen Bestehens hiermit die besten Wünsche: Möge es der Akademie vergönnt sein, wie im abgelaufenen Jahrhundert so auch fernerhin die Naturwissenschaften zu pflegen und zu fördern.

Namens der Universität Heidelberg
v. DUHN
d. Zt. Prorektor.

The Academy of Natural Sciences of Philadelphia.

K. K. UNIVERSITÄT, WIEN.

AKADEMISCHER SENAT
DER K. K. UNIVERSITÄT
WIEN
Z. 884 ex 1911/12.

Wien, am 23. Februar 1912.

Euer Hochwohlgeboren hatten die Freundlichkeit, die Universität Wien zur Teilnahme an der am 19., 20. und 21 März 1912 stattfindenden hundertjährigen Bestandfeier der Akademie einzuladen.

Leider ist infolge anderweitiger bereits übernommener Verpflichtungen der in Betracht kommenden Persönlichkeiten die Entsendung eines Vertreters zu dem Feste unmöglich geworden und ich muss mich daher begnügen, auf diesem Wege zugleich mit dem Danke der Wiener Universität für die freundliche Einladung auch die besten Glückwünsche zu dieser Feier zu übermitteln.

Der Rektor k. k. Universität:
REDLICH

To The Academy of Natural Sciences of Philadelphia.

UNIVERSITÄT, ZÜRICH.

Zürich, den 1. März 1912.

Das Rektorat der Hochschule Zürich an die Academy of Natural Sciences of Philadelphia:

Empfangen Sie verbindlichen Dank des unterzeichneten Rektors und des Senates der Universität Zürich für die freundliche Einladung zu dem bevorstehenden 100jährigen Jubelfest Ihrer Academie.

Leider ist es uns nicht vergönnt, uns durch eine persönliche Abordnung an dem Feste vertreten zu lassen; um so mehr drängt es uns, Ihnen unsere besten Glückwünsche darzubringen für die Anerkennung, welche Ihre Academie durch ihre wissenschaftliche und erzieherische Wirksamkeit sich erworben hat. Wir verbinden damit den Ausdruck unseres herzlichen Wunsches und unserer zuversichtlichen Hoffnung, dass Ihre Academie in gesegneter Weise weiter wirken möge für die Erkenntnis der Wahrheit und für das Wohl des Volkes.

In diesem Streben wissen wir uns mit Ihnen verbunden zu einer von den nationalen Grenzen nicht gehemmten Einheit des Geistes.

Zugleich wünschen wir Ihrem Feste einen glücklichen Verlauf.

Im Namen der Universität Zürich

i. A. Der z. Rektor:

ARNOLD MEYER

Prof. publ. ordin. S.S. Theologiæ Doctor.

UNIVERSITÉ CATHOLIQUE DE LOUVAIN.

Louvain, le 24 fevrier 1912.

Monsieur le Secrétaire:

Je suis chargé d'exprimer à l'Académie des Sciences naturelles de Philadelphie, les remerciments de l'Université de Louvain, pour sa gracieuse invitation aux fêtes du Centenaire de cet illustre Corps savant.

L'Université de Louvain regrette vivement que l'époque choisie pour la célébration de ces fêtes ne permette pas à ses professeurs de s'absenter, et forme ainsi obstacle à l'envoi d'un délégué. Force lui est donc de se borner à s'associer de loin, mais de tout cœur, aux félicitations et aux vœux qui, en ces jours, seront addressés à l'Académie de Philadelphie.

Veuillez agréer, Monsieur le Secrétaire, l'assurance de ma haute considération.

Pour le Conseil Rectoral
Le Secrétaire
J. VAN BIERVLIET

A Monsieur le Secrétaire de l'Académie des Sciences Naturelles de Philadelphie.

UNIVERSITÉ DE LYON.

Lyon, le 27 Février 1912.

La jeune Université de Lyon est heureuse d'adresser par delà l'Atlantique son salut le plus cordial à l'Académie des Sciences Naturelles de Philadelphie et d'exprimer à sa sœur ainée Américaine ses sentiments d'affectuese confraternité et ses félicitations les plus vives à l'occasion des fêtes du Centenaire de cette illustre Compagnie.

Tous les naturalistes d'Europe qui ont visité la grande cité de Philadelphie connaissent, pour les avoir longuement admirées la magnifique bibliothèque de l'Académie des Sciences Naturelles et ses remarquables collections dues à l'initiative et aux travaux de deux savants illustres entre tous dans les annales de la science paléontologique, Jos. Leidy et Edw. Cope. C'est sous les auspices de ces deux hommes éminents que l'Université de Lyon désire placer cette adresse destinée à apporter aux naturalistes de Pennsylvanie, à défaut d'un représentant attitré l'hommage de sa sincère admiration, et de sa plus profonde sympathie.

Le Recteur,
Président du Conseil de l'Université,
P. JOUBIN.

R. Universiteit, Leiden.

Academiæ Disciplinarum Physicarum Philadelphiensi S. p. d. Universitatis Lugduno-Batavæ Rector et Senatus.

Quod nos ad ferias sæculares mense Martio Vobis celebrandas invitatis insigni nos a Vobis affectos honore penitus sentimus. Quo magis dolemus quod magnum terrarum mariumque spatium quominus humanissima illa invitatione utamur obstat. Sed quamquam lactis illis diebus e nostro munero nemo istuc legari poterit, tamen omnes mente animoque tunc Vobiscum gaudebimus. Et iam nunc pro illustri Vestra Academia ex animi sententia vota suscipimus solemnia.

Vivat, crescat, floreat et facem humanitatis præferre omnibus pergat quibus bonæ artes cordi sunt!

Lugd. Batav. die XXVII Menis Februarri MCMXII

F. Pijper
Rector magnificus.
B. D. Erdmans,
Actuarius.

On folio sheet with seal of University.

University of Cambridge.

Registry of the University of Cambridge, England, 14 March, 1912.

To the President of The Academy of Natural Sciences of Philadelphia.

Sir:

I have the honor to inform you that the Senate of the University at a congregation held this day in the Senate House appointed Ernest William Brown, Doctor of Science, formerly Fellow of Christ's College, Professor of Mathematics in the University of Yale, to represent the University at the Centenary Anniversary of the Academy of Natural Sciences of Philadelphia in March, 1912.

I have the honor to be, Sir,

Your obedient Servant
John Neville Keynes,
Registrary.

Seal.

UNIVERSITY OF CINCINNATI.

Office of the President.

The President and Faculties of the University of Cincinnati acknowledge, with much appreciation, the invitation to be represented at the celebration of the One hundredth Anniversary of the Academy of Natural Sciences of Philadelphia. They regret that it is not possible to send a delegate to convey to the members of the Academy their hearty congratulations upon the completion of one hundred years of noble service, and their cordial good wishes for the successful continuation of its important work.

The twentieth of March, Nineteen Hundred and Twelve.

UNIVERSITY OF COLORADO.

The University of Colorado begs to convey to The Academy of Natural Sciences of Philadelphia its most sincere congratulations on the occasion of the Centenary of the Academy. At a time when our State was a wilderness unvisited by scientific men, the Academy was laying the foundations of American Biological Science. During the past century its unceasing activities have contributed enormously to the knowledge of the fauna and flora of the West. We hope that the Academy will enjoy even greater prosperity in the future than it has in the past, and that the coming century will see active cooperation between it and our developing western institutions.

Beautifully engrossed.

UNIVERSITY OF EDINBURGH.

20th March, 1912.

Dear Sir:

On behalf of the Senatus Academicus of the University of Edinburgh, I beg to convey cordial thanks to The Academy of Natural Sciences of Philadelphia for the invitation to be represented at the Celebration of the Academy's Centenary Anniversary. I am to say that the Senatus greatly regret that the invitation did not reach them in sufficient time to enable them to arrange for the attendance of Delegates.

The Senatus send their warm congratulations to the Academy on the auspicious occasion and their best wishes for the Academy's future prosperity, and they trust the Celebrations are being carried through with the greatest success.

Yours faithfully,

L. J. GRANT,

Sec. Sen. Acad.

Corresponding Secretary, The Academy of Natural Sciences of Philadelphia.

University of Notre Dame.

Notre Dame, Indiana, June 1, 1912.

To the Secretary of The Academy of Natural Sciences of Philadelphia.

Sir: The Centenary of The Academy of Natural Sciences of Philadelphia offers an appropriate and most welcome occasion to express the admiration which the University of Notre Dame has always entertained for the work of that distinguished body. The history of its activities during the hundred years of its existence shows its connection with so many of the great achievements and its services to individuals and causes have been so great and so many that the story of the Academy must have an important place in any history of scientific development in the nineteenth century.

Its work has been done unselfishly and in a spirit of high devotion to the advancement of learning and the profit of humanity. For this reason the world of learning acclaims it in its centenary year and wishes it continued power in its beneficent mission.

The University of Notre Dame feels it an honor to associate itself with the great schools that pay tribute to this venerable Academy.

Very truly yours,

John Cavanaugh, C.S.C.,
President.

University of Pennsylvania.

The Provost, Trustees, and Faculties of the University of Pennsylvania cordially congratulate The Academy of Natural Sciences of Philadelphia on its Centennial Celebration to be held upon March 19th to 21st, and extend their best wishes upon this auspicious occasion.

The Provost has commissioned Josiah Harmar Penniman, Ph.D., LL.D., the Vice Provost of the University, to represent it at the ceremonies and to be the personal bearer of its congratulations.

(*Seal*)

Edward Robins,
Secretary to the Board of Trustees.

Philadelphia, Pa., March 19th, 1912.

University of Pittsburgh.

The University of Pittsburgh extends its greetings and congratulations to the Academy of Natural Sciences of Philadelphia upon the completion of one hundred years of its honorable and useful career and expresses its best wishes for greater prosperity and an enlarged sphere of achievement during the coming years in the important field which it occupies.

Samuel Black McCormick, Chancellor, William Jacob Holland, former Chancellor, and George Hubbard Clapp, President of the Board of Trustees, are appointed delegates of the University at the Centennial Anniversary and are authorized to present these greetings.

Samuel Black McCormick,
Chancellor.
S. B. Linhart,
Secretary.

Pittsburgh, Pennsylvania, March Eighteenth, Nineteen Hundred and Twelve.

University of Virginia.

University of Virginia, March 12, 1912.

The President and Faculty of the University of Virginia desire to present to The Academy of Natural Sciences of Philadelphia their hearty congratulations on the completion of a century of scientific activity and achievement. Founded at a time when the study of nature in this country was followed by but few students, and organized societies for the advancement of such study were in existence at but two or three widely separated points, the Academy has held an honorable place and has contributed largely to the results of scientific research in America. May the second century of its existence be marked by as vigorous and fruitful life as that which closes so auspiciously.

Edwin A. Alderman,
President.

C. K. Universytet imienia cesarza Franciszka i Lemberg.

The Rector and the Senate of the Universytet imienia cesarza Franciszka I in Lemberg have the honor hereby to transmit their sincere congratulations and the expressions of highest esteem and respectful friendship to The Academy of Natural Sciences of Philadelphia, on the day when the Academy is celebrating the joyful event of its Centenary Anniversary.

The University of Lemberg is one of the only two surviving Polish universities, while the places of learning in other parts of Poland have been destroyed by foreign tyrannic force and oppression.

The University sympathizes deeply with the Academy, as one of the most ancient and most renowned scientific institutions of the New World, not only because of the common bond of affinity, uniting the learned societies and institutions of all countries and all nations, but also because the Academy is a representative of the Country of Freedom.

May the Academy continue the scientific work which has made famous its name all over the world, and may Science contribute towards raising of mankind from tyrannic barbarism to real humanity.

Lemberg, March 10th, 1912.

L. Finkel,
Rector of University.

The Academy of Natural Sciences of Philadelphia.

VEREIN FÜR VATERLÄNDISCHE NATURKUNDE IN WÜRTTEMBERG.

Stuttgart, den 16 Februar 1912.

Academy of Natural Sciences of Philadelphia:

Indem ich für die ehrenvolle und freundliche Einladung zur 100-Jahrfeier Ihrer Gesellschaft meinen verbindlichsten Dank ausspreche, möchte ich mir erlauben, namens des Vereins für vaterländische Naturkunde in Württemberg Ihrer Akademie die wärmsten Glückwünsche zu dieser Feier auszudrücken. Mit Stolz kann Ihre Akademie auf die hundertjährige Tätigkeit zurückblicken, in welcher sie für die wissenschaftliche Durchforschung der Vereinigten Staaten so Ausserordentliches geleistet hat. Seien Sie überzeugt, dass auch unsere Gesellschaft Ihre Bestrebungen im vollsten Maasse anerkennt und Sie zu Ihren Erfolgen beglückwünscht.

Leider ist es mir nicht möglich, persönlich unsere Glückwünsche zu überbringen, und ich bitte deshalb, dieselben auf diesem Wege anzunehmen.

Mit dem Ausdruck vorzüglicher Hochachtung Der Vorsitzende des Vereins für vaterländische Naturkunde in Württemberg

PROFESSOR DR. E. FRAAS.

VEREIN ZUR VERBREITUNG NATURWISSENSCHAFTLICHER KENNTNISSE IN WIEN.

IV., k. k. technische Hochschule.

An die Academy of Natural Sciences of Philadelphia:

Der Verein zur Verbreitung naturwissenschaftlicher Kenntnisse in Wien sendet The Academy of Natural Sciences of Philadelphia zur 100 Jahrfeier die besten Glückwünsche.

In den ersten Jahrzehnten des Bestandes der Vereinigten Staaten, als erste naturwissenschaftliche Gesellschaft daselbst gegründet, hat The Academy of Natural Sciences of Philadelphia bis heute in ausgedehntem Masse die naturwissenschaftliche Erkenntnis in ihrem Vaterlande gefördert und sich dadurch grosse Verdienste erworben. Dass diese bedeutende Tätigkeit der Academie noch recht lange andauern möge, wünscht unser Verein aufrichtigst.

HOFR. PROF. DR. FRANZ TOULA,
1st Vice Präsident.

Wien, am 23. Februar 1912.

THE WISTAR INSTITUTE OF ANATOMY AND BIOLOGY, PHILADELPHIA.

To the Academy of Natural Sciences of Philadelphia:

The Wistar Institute of Anatomy and Biology extends its felicitations and congratulations to The Academy of Natural Sciences of Philadelphia and, owing to the close affiliation which exists between the two institutions, joins with special satisfaction in the celebration of the Centenary Anniversary.

On this occasion, The Wistar Institute delegates its Director as the Representative to take part in these festivities.

EDGAR F. SMITH,
President
MILTON J. GREENMAN,
Secretary.

March 19, 1912.

K. K. ZOOLOGISCH-BOTANISCHE GESELLSCHAFT, WIEN.

111/3, Mechelgasse Nr. 2.

To The Academy of Natural Sciences of Philadelphia:

The K. K. Zoologisch-Botanische Gesellschaft sends by the present her cordial congratulations for the honourable commemoration to the Academy of Natural Sciences of Philadelphia.

On this occasion she thinks thankfully on the great merits which the Academy has acquired for the advancement of the science in general and the organization of scientifical works in North America and joins in the sincere wishes for the future and begs of continuation of the cordial relations.

Vienna, the 8th March, 1912.

Das Präsidium der K. K. Zoologisch-Botanischen Gesellschaft.

PROF. DR. R. v. WETTSTEIN,
Praesident.
DR. FRANZ OSTERMEYER
Vice Praesident.

ZOOLOGISCHE GESELLSCHAFT, HAMBURG.

Hamburg, den 15 Febr. 1912.

Mit dem Ausdruck verbindlichsten Dankes bestätigt die Zoologische Gesellschaft in Hamburg die Einladung zur Beteiligung an der Feier des hundertjährigen Jubilaeums der Academy of Natural Sciences of Philadelphia,—Die Zoologische Gesellschaft wird leider nicht in der Lage sein durch einen Vertreter an diesem Ehrentage teilzunehmen und der Jubilarin ihre aufrichtigsten Glückwünsche zu übermitteln. Sie bittet dies zu entschuldigen und auf diesem Weg die Versicherung entgegenzunehmen, dass ihre besten Wünsche für ein ferneres Blühen und Gedeihen die Academy in das zweite Jahrhundert ihres Bestehens begleiten.

Die Zoologische Gesellschaft in Hamburg. Der Vorstand.
PROF. DR. F. VOSSELER.

The Academy of Natural Sciences of Philadelphia.

K. ZOOLOGISCHES UND ANTHROPOLOGISCH-ETHNOGRAPHISCHES MUSEUM.

Dresden A, Zwinger, 13 Februar 1912.

An die Academy of Natural Sciences Philadelphia:

Mit Interesse habe ich davon Kenntnis genommen, dass die Academy, eine der ältesten Pflanzstätten der Naturwissenschaften in der Neuen Welt, demnächst die Feier ihres 100jährigen Bestandes begehen wird. Wenn ich auch nicht in der Lage bin, die Glückwünsche der von mir geleiteten Anstalt selbst zu überbringen, so benutze ich doch die mir gütigst übermittelte Einladung dazu, um Ihrer Körperschaft meine Freude über die Vollendung jenes Zeitabschnittes auszusprechen, zugleich mit dem Ausdrucke meiner wahren Verehrung für die währenddem von ihr zutage geförderten grossen Leistung auf unserem gemeinsamen Arbeitsgebiete. Ich knüpfe daran den aufrichtigen Wunsch, dass die weitere Entwicklung der Academy ihr jederzeit erlauben möge, ihren selbstgesteckten Zielen mit gleicher Tatkraft und mit denselben schönen Erfolgen nachzustreben, wie es im verflossenen Jahrhundert der Fall war.

In aller Hochschätzung

A. JACOBI
Direktor.

Other letters were received from the following:

R. Academia de Ciencias y Artes de Barcelona. Louis M. Vidal, President.

Academia Nacional de Historia, Bogotá. Pedro M. Haüer.

Académie d'Arras. G. Acrement, President.

Académie des Sciences Inscriptions et Belles-Lettres de Toulouse. Henri Duméril, Secrétaire perpétuel.

R. Accademia dei Fisiocritici, Siena. Prof. Dominico Barduzzi, President.

Accademia Scientifica Veneto-Trentino-Istriana, Padova. Prof. G. Dal Piaz, President.

R. Accademia delle Scienze di Torino. Charles Sedgwick Minot.

R. Accademia di Scienze, Lettere ed Arti, Modena. Francesco Nicoli, President.

American Academy of Arts and Sciences, Boston. Edwin H. Hall, Corresponding Secretary.

American Physiological Society. S. J. Meltzer, President; A. J. Carlson, Secretary.

K. Anatomisches Institut, Halle a S. W. Roux.

Anthropological Society of Bombay. Jivanji Jamshedji Modi, Hon. Secretary.

Archæological Institute of America, Pennsylvania Society. George Barton, Secretary.

Asiatic Society of Bengal, Calcutta. G. H. Tipper, Hon. Secretary.

Lord Avebury, London.

Ayers, Howard, Cincinnati.

Baltzer, A., Bern.

Barrois, Charles, Paris.

Bataafsh Genootschap der Proefondervindelijke Wijsbegeerte te Rotterdam. Dr. R. H. van Dorsten, 1st Secretary.

K. Bayer. Julius-Maximilians-Universität, Würzburg. Karl Bernhard Lehman, Rector.

K. Bayer. Oberbergamt, München. Ludwig v. Ammon.

Bedel, L., Paris.

Berliner Entomologischer Verein. Paul Schulz, Secretary.

Biltmore Herbarium. C. D. Beadle, Director.

Biologische Versuchsanstalt in Wien. H. Przibram, Director.

R. Botanic Garden, Calcutta. A. T. Gage, Superintendent.

R. Botanic Gardens, Kew. D. Prain, Director.

R. Botanic Gardens, Peradeniya, Ceylon.

Boulenger, G. A., London.

Brady, Dr. G. S., Sheffield.

Branner, John Casper, Stanford University.

Britton, N. L., New York.

Brown University, Providence. W. H. P. Faunce, President.
Brunton, Sir Lauder, London.
Bureau of Science, Manilla. Richard P. Strong.
California State Mining Bureau, San Francisco. W. H. Storms, State Mineralogist.
Capellini, Prof. Giovanni, Bologna.
Cardiff Naturalists' Society. William Sheen, President.
Carnegie Institute of Pittsburgh. W. N. Frew, President; S. H. Church, Secretary.
Carnegie Institution of Washington, Station for Experimental Evolution, Cold Spring Harbor.
Cartailhac, Emile, Toulouse.
Centro de Sciencias, Letras e Artes, Campinas.
Chantre, Ernest, Fontville, par Ecully, Rhône.
Club Alpin de Crimée et du Caucase, Odessa. E. Molthanoff, Vice-President; A. Alexejev, Secretary.
Club Alpin Suisse. Charles Maerky, Secretary.
Cockerell, Theo. D. A., Boulder, Colorado.
Collett, R., Christiania.
Colorado College, Colorado Springs. Jonathan A. Rorer, Ph.D.
Cooke, M. C., London.
Danische Laboratorium für Süsswasser Biologie. D. Wesenburg-Lund, Director.
Dansk Botansk Forening, Kobenhavn. L. Kolderup Rosenvinge, President.
Danske Biologisk Station, Kobenhavn. C. G. Joh. Petersen.
K. Danske Videnskabernes Selskab, Kobenhavn. H. G. Zeuthen, Hon. Secretary.
Davenport Academy of Sciences. J. H. Paarman, Secretary.
Delaware Valley Ornithological Club. Samuel C. Palmer, Sec. pro tem.
Department of Agriculture, Cape Town.
Department of Agriculture, Kingston. H. H. Cousins, Director.
Department of Agriculture, Trinidad and Tobago. W. G. Freeman, Asst. Director.
Department of Commerce and Labor, Bureau of Fisheries, Washington, D. C. George M. Bowers, Commissioner.
Department of Commerce and Labor, Coast and Geodetic Survey, Washington, D. C. O. H. Tittmann, Superintendent.
Department of Mines, Perth. H. L. King, Secretary.
Deutsche Mikrologische Gesellschaft, München. Rl. Francé.
Deutscher Verein zum Schutze der Vogelwelt, Gera-Reuss. Dr. Hennicke.
Deutscher und Oesterreichischer Alpenverein, Wien. Dr. Duges.

École Nationale d'Agriculture de Montpellier. Paul Ferrouillat, Director.

Entomological Society of Ontario. F. M. Webster.

Essex Institute, Salem. George Francis Dow, Secretary.

Field Naturalists' Club, Brisbane. C. W. Holland, Hon. Secretary.

Forel, Dr. A., Yvorne.

Friedrich Wilhelms-Universität, Berlin. M. Lenz, Rector.

Fürbringer, Max., Heidelberg.

Geikie, Archibald, London.

Geological Society of South Africa, Johannesburg. W. W. R. Jags, Asst. Secretary.

Geological Society of Tokyo. N. Yamasaki, Hon. Secretary.

Geological Survey of India, Calcutta.

R. Geologisch-Mineralogisch Museum, Leiden. K. Martin.

Gesellschaft für Erdkunde, Berlin. Alb. Penck, Vorsitzender.

Gesellschaft für Erdkunde zu Leipzig. Herm. Reishauer, Secretary.

Gesellschaft von Freunden der Naturwissenschaften, Gera-R. Fr. Moos, Anton Renz, With. Israël, Franz Weise, Ernst Kretschmer, Alfred Auerbach.

Gesellschaft für Morphologie und Physiologie, München. Ludwig Neumayer, M.D., President.

Gesellschaft für Natur- und Heilkunde zu Dresden. Prof. Dr. Rietschel, Secretary.

Gesellschaft für Voelker- und Erdkunde zu Stetten. G. Buschan, President.

Gill, Dr. Theo. N., Washington, D. C.

Godman, F. D., Horsham.

Göteborgs Museum. Carl Lagerburg, Director.

Goldschmid, V., Heidelberg.

Gosselet, J., Lille.

Government Fisheries Bureau, Tuticorin. James Hornell, Superintendent.

Government Museum, Madras.

Graff, L. v., Graz.

Grant, Sir James, Ottawa.

Guernsey Society of Natural Science. T. W. M. de Guerin, President.

Haeckel, Ernst, Jena.

Herculais, Jules Künckel d'.

Hertwig, Richard, München.

Hirase, Y., Kyoto.

Hirnanatomisches Institut, Zürich. Constantin v. Monakow, Director.

Hochstetter, A., Wien.

Hoernes, Moritz, Wien.

Hoyle, William Evans, Cardiff.
Hubrecht, A. A. W., Utrecht.
Hygienic Laboratory, Washington, D. C. John F. Anderson, Director.
Indian Museum, Calcutta. N. Annandale, Secretary.
Institut Général Psychologique, Paris.
Institut National Genevois. B. P. C. Hochreutiner, Secretary.
Institute of Jamaica, Kingston. Frank Cundall, Secretary.
Instituto Geologico de Mexico. José G. Aguilera, Director.
Instituts Solvay, Bruxelles. Emile Wexweiler, Director.
Institutul Geologic al României, București. V. Popovici-Hatzeg, Director.
Iowa Academy of Science, Des Moines.
R. Irish Academy, Dublin.
Jardin Impérial de Botanique de St. Pétersbourg. A. Fischer de Waldheim, Director.
Judd, John W., Kew.
Jugoslavenske Akademije Znanosti i Umjetnosti, Zagreb. Dr. A. Musić, Secretary.
K. k. Karl Franzens-Universität, Graz. Franz Hauke, Rector.
Kjobenhavns Universitet. F. Buhl, Rector.
Lang, Arnold, Zürich.
Lankester, Sir Ray, London.
K. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher, Halle. A. Wangerin, President.
Libbey, William, Princeton.
Lunds Universitet, Lund. Axel Koch, Principal.
K. Lyzeum Hosianum zu Braunsberg. Jos. Kolberg, Rector.
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Acknowledgment of these communications was made as follows, embodying the action of the Academy taken at the meeting of April 16, 1912:

Resolved: That The Academy of Natural Sciences of Philadelphia finds much encouragement and stimulus in the expressions of cordial congratulation and recognition of its labors that reached it on the occasion of the celebration of the Centenary Anniversary of its Foundation.

Resolved: That the Corresponding Secretary be instructed to convey to corresponding institutions and members an expression of the Academy's warm gratitude for their appreciation and courtesy.

Samuel G. Dixon,
President.

J. Percy Moore,
Corresponding Secretary.
Edward J. Nolan,
Recording Secretary.

II.

Memoirs.

A pathetic incident of the first session of the centenary celebration of the Academy was the announcement of the death that morning (March 19, 1912) of Thomas Harrison Montgomery, Jr., Ph.D. He had contributed the first memoir to this commemorative volume and had taken an active and generous interest in the anniversary. The paper which follows is the last written by Dr. Montgomery and the untimely conclusion of his labors is deeply regretted. Eloquent testimony to his charm as a man and his ability as a student has been borne elsewhere. The superior quality of his work and the importance of the discoveries that had already rewarded his researches gave promise of a future career of unusual distinction as a biological investigator. The Academy deplores the loss of an earnest, conscientious, and generous associate.

E. J. N.

Human Spermatogenesis
Spermatocytes and Spermiogenesis
A Study in Inheritance

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PLATES I, II, III, IV

PHILADELPHIA
1912

HUMAN SPERMATOGENESIS, SPERMATOCYTES AND SPERMIOGENESIS: A STUDY OF INHERITANCE.

By Thomas H. Montgomery, Jr., Ph.D.

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Introduction.

It is remarkable that human spermatogenesis has never been thoroughly studied, and that the literature upon it consists chiefly of scattered small contributions, many of ancient date. The mature spermatozoa have been repeatedly investigated and with great care, but the earlier stages have for the most part been only briefly treated. Yet it is necessary to understand these processes in order to secure a mechanical basis for our knowledge of human inheritance.

The material studied consisted of pieces of the testis, epididymis and vas deferens of a negro, preserved in Zenker's fluid shortly after the man's death, by Dr. W. H. F. Addison, of the University of Pennsylvania. I am exceedingly obliged to this gentleman for the gift of such valuable material. According to the records of Dr. Addison, and of Dr. Hewson, Secretary of the Anatomical Board of the State of Pennsylvania, the man was "very black," healthy, aged about 50, hung by law 26 Feb., 1907, with the Moyamensing Prison number 205 A.B. The fixation of this material was on the whole excellent, except that cytoplasmic details were not as well preserved as one generally finds in material preserved in Fleming's fluid; unfortunately the mitochondria were dissolved. In addition to this, Prof. Guyer most generously gave me portions from the testis of another negro, in which he had discovered the modified chromosomes, these pieces being fixed in the fluids of Gilson and Bouin. Almost all my observations were made

upon the Zenker's fluid material, for it seemed to show on the whole better preservation than the other and exhibited the individual chromosomes much more distinctly; the chromosomes after use of the other fixations named appeared much more swollen and frequently even agglomerated. Paraffine sections were stained by the iron hæmatoxyline method, usually followed by eosin, with safranine, and, possible only upon Bouin's fluid material, with the Ehrlich-Biondi-Heidenhain triple stain. A large number of slides were prepared and each section carefully examined for mitoses, and in this way much time was devoted simply to finding maturation mitoses.

In a previous paper the history of the Sertoli cells was given by me. In the present one the stages from the late growth period to the mature spermatozoa will be treated.

I. The Spermatocytes and their Divisions.

A. OBSERVATIONS.

1. *Primary Spermatocytes.*

The greater number of spermatocytes do not exceed in size those shown in figs. 2–25, Pl. I. Rarely one finds amongst these small groups of much larger primary spermatocytes, of which one is drawn in fig. 1. These giant spermatocytes are so seldom found that they should be considered abnormalities; and the only one of them seen in division exhibited a large number of chromosomes (more than 32). We will disregard these giant cells in the following account.

It is sometimes difficult to distinguish sharply and positively primary from secondary spermatocytes. Late growth period stages of the primary ones are easily distinguished (figs. 2–6), for they exhibit the strepsinema form of chromosomes so characteristic of corresponding cells in most animals. But to distinguish the first from the second maturation division is often difficult. Volume of the cell or nucleus alone is not always a sure criterion, for the spermatocytes vary considerably in volume; position within the seminiferous tubule gives no clue, for all spermatocytes lie near the axial lumen, only spermatogonia being at the periphery. Also in both mitoses there appear to be two centrioles at each pole, so that number of these offers no distinction. The surest criteria between the primary and secondary spermatocytes is that in the former the chromosomes are larger and certain of them are more or less distinctly quadripartite, while in the secondary spermatocytes they are smaller and usually in the form of distinct dyads. Also in the primary cells the spindles are usually relatively longer. On account of these difficulties I cannot be certain that in all cases I have correctly assigned the generation of a cell, but I believe I have done so in the greater number.

In the later growth period two kinds of bodies are usually to be found within the nuclei. First, generally two plasmosomes, (Pl. I, figs. 2–8, 11, 12); these are rounded and lie within the nuclear membrane. Parts of one or both

of these plasmosomes would seem to be those granules frequently found near the spindle poles during division (figs. 15–17, 19–23). Distinct from these are two dense bodies, or different volumes, the allosomes or modified chromosomes, which always lie against the nuclear membrane. The name "allosomes" to denote modified chromosomes was introduced by me in an earlier paper (1906). Sometimes the two are separated (*D*, *d*, figs. 3, 6); sometimes in close contact (figs. 2, 4, 5). Only by the Ehrlich-Biondi triple stain, used after Bouin's fixation, can the plasmosomes be sharply distinguished from the allosomes; the former then stain red (acidophilic), the latter, like the chromosomes, green (basophilic). The later history will make it clear that the basophilic bodies are true allosomes and not chromatoid nucleoli. These are probably allosomes of the kind called by Wilson idiochromosomes, for they appear to become first differentiated in the spermatocytes. The larger of the allosomes we will call *D*, and the smaller *d*.

Late prophases (diakinesis) of the first maturation mitosis are shown in figs. 7–12, of which the last four exhibit all the chromosomes. In figs. 10 and 11 exactly 12 chromosomes can be seen; this is also the case in figs. 9 and 12, provided the bodies marked *x* is each a geminus. Ten of these 12 must be gemini or bivalent chromosomes judging by their later history and by analogy with other species; they exhibit great form diversity, the elements of a geminus being connected terminally or laterally, or irregularly bent around each other. Until their method of formation is known it would be useless to speculate as to their exact constitution, and as to whether it is in the first or second maturation mitosis that they divide reductionally. The two remaining elements are the univalent allosomes, but in these late prophases it is practically impossible to say which two these are.

In the first maturation mitosis several variations may be distinguished, with regard to the behavior of the two allosomes, as follows:

Condition A, both allosomes lying at the same spindle pole, found in 59 cases. This is shown in figs. 13–17. The polar view, fig. 13, shows 10 ordinary chromosomes (autosomes), and at a different level from these the two allosomes (*D*, *d*), while figs. 14–17 show the same condition on lateral view; fig. 14 shows all the chromosomes.[1]

Quite frequently each of the allosomes shows a longitudinal split (figs. 14, 17). In this condition *A* both allosomes must pass undivided into one of the secondary spermatocytes.

Condition B, allosome *D* lying at one pole, allosome *d* at the opposite pole, found in 5 cases (Fig. 18). As a result of this one secondary spermatocyte should receive *D*, and the other *d*.

Condition C, allosome *D* at one pole, while *d* has divided and one of its products lies at one spindle pole (figs. 19–22). This was found in 10 cases. In figs. 19 and 21 all the chromosomes are drawn. As a result of a division of any such

[1] In all figures only those chromosomes are drawn that can be seen distinctly, the others are omitted.

case, one of the daughter secondary spermatocytes would receive *D* and a half of *d*, the other would receive only a half of *d*.

Condition D, the smaller allosome, *d*, at one pole, none at the other, *D* being then probably in the equator. This was seen in 5 cases (fig. 23). In this condition *D* probably divides in the equator along with the other chromosomes, consequently one daughter cell would receive *d* and a half of *D*, and the other would receive a half of *D*.

Condition E, both *D* and *d* divide equationally, found in 3 cases. This is seen distinctly in fig. 25; in fig. 24 the spindle is very oblique, causing the two dividing allosomes to appear nearer one pole than they really are. Each secondary spermatocyte would then receive a half of *D* and a half of *d*.

The remaining conditions concern variations in the distribution of the ordinary chromosomes.

Condition F, one entire undivided geminus at one spindle pole, found in 3 cases (fig. 26, Pl. II). In the case figured both allosomes are at the same pole. Following division of such a cell one secondary spermatocyte should receive two more dyads than the other.

Condition G, one geminus dividing precociously so that one dyad lies at one pole and one dyad at the opposite pole, found in 3 cases. Fig. 27 illustrates this condition; in the left hand cell both allosomes are at one pole, a combination of conditions *A* and *G*; in the right hand cell both allosomes have divided, so that at each pole there is a half of a geminus, a half of *D* and a half of *d*. This condition *G* is only a slight variation, a precocious division of a geminus, it cannot lead to any change in the number of dyads in the secondary spermatocytes.

The anaphase of the first maturation mitosis is drawn in fig. 28, telophases in figs. 29–33, showing that a marked interkinesis or rest stage follows this division. In the stages of figs. 32, 33 compact bodies are found within the nuclei of the daughter cells, secondary spermatocytes. These bodies are not fixed in number, some being allosomes and some plasmosomes, as can be determined by the Ehrlich-Biondi stain. The preparations from which these figures are made were stained by iron-hæmatoxyline, which does not give a staining difference between the two kinds of bodies.

2. *Secondary Spermatocytes.*

Late prophases of the second maturation mitosis are shown in figs. 34–36, Pl. II, in each of which all the chromosomes are shown. Figs. 34 and 35 show each 12 chromosomes and each probably contains two allosomes, fig. 36 exhibits 11 chromosomes and therefore probably contains only one allosome.

Two polar views of second maturation spindles are given in figs. 37, 38, the former showing 10 chromosomes, the latter 12; the latter contains the allosomes *D*, *d*, lacking in the former. The ordinary chromosomes are here well marked dyads, appearing longitudinally cleft; they are quite different in appearance from the heavier chromosomes of the previous mitosis (fig. 13). Several variations can be distinguished in the mode of division of the chromosomes:

Condition a, all chromosomes divide at the plane of the equator, found in 104 cases. This is shown in figs. 38–41, of which all but the last exhibit the total number of chromosomes (12). The allosomes are probably those lettered *D* and *d*. This condition must have followed conditions *A* or *B* of the primary spermatocytes. Fig. 41 shows an unusually small secondary spermatocyte, but all grades in size are to be found between it and such a large cell as fig. 47.

Condition b, like the preceding condition, but the allosomes dividing precociously as exhibited in fig. 42. This was found in two instances. In conditions *b* and *a* the daughter cells, spermatids, would receive precisely equivalent chromosomes.

Condition c, one split chromosome, polar-lateral from the others, found in only one case and drawn in fig. 43. (This figure shows all 12 chromosomes.) This misplaced chromosome is probably *d*, and should it be transmitted entirely to one spermatid, that cell would receive an entire allosome that had not divided.

Condition d, one chromosome to the side of the equator (fig. 44), found in one case. This displaced chromosome would seem not to be an allosome, judging by its size.

Condition e, an unsplit allosome at one pole of the spindle, found in 19 cases. Sometimes (fig. 45) this body appears to be *D*, judging from its size, in other cases (fig. 46) to be *d*. These cases evidently result from condition *C* or *D* of the primary spermatocytes; and of the spermatids resulting, half would have one allosome (either $\frac{1}{2}D$ or $\frac{1}{2}d$) and half would have none.

Condition f, three unsplit chromosomes at one pole, none at the other (fig. 47), found in one case. It is difficult to explain this except by assuming that two of these bodies are the separated halves of one allosome (a further step in condition *c*), while the third is the other allosome (as in condition *e*). Following such a division one spermatid would get no allosomes, the other spermatid would get one part of one allosome and both parts of the other allosome.

Condition g, one unsplit allosome at one pole, another unsplit allosome at the opposite pole (fig. 48), observed in one case. This must have followed a first maturation mitosis where both allosomes divided in the equator; and it would result in giving to one spermatid a half of the larger allosome (*D*), and to the other spermatid a half of the smaller allosome (*d*).

The following conditions of variance refer to the ordinary chromosomes:

Condition h 1, one entire dyad at one pole (fig. 49), seen in 9 cases. This would result in one spermatid receiving two monadic chromosomes more than the other spermatid.

Condition h 2, two dyads, of different sizes, at one pole (fig. 50, Pl. III), observed in 2 cases. Here one spermatid would receive four monadic chromosomes more than the other spermatid.

Condition h 3, correspondent dyads at opposite poles of the spindle (fig. 51), noted in 1 case. This must have resulted from a case of condition *F* (fig. 26) of a primary spermatocyte, where an entire tetrad passed undivided to one pole,

and where consequently its normal division was delayed until the second maturation mitosis. Each resulting spermatid would contain one more monad than is normal.

Condition h 4, non-homologous dyads at opposite poles of the spindle (fig. 52), found in 1 case. In this case each spermatid would contain the usual number of monadic chromosomes, but each would lack one of a kind normally found in it.

Fig. 53 shows an anaphase, and figs. 54, 55 show telophases of the second maturation mitosis, the most distinct chromosomes only being drawn. In fig. 55 is seen quite a regular condition for man, but one not observed by me in other objects, the nuclei of the spermatids developing at unequal rates.

Brief mention may be made of the other structures during the maturation mitoses. The mantle fibers are distinct, the polar fibers much more delicate and often scarcely visible. There is a pair of minute centrioles at each pole during both mitoses. The behavior of the centrioles in the diakinesis could not be made out, nor any trace of the spindle before its complete formation, except that in a few cases (figs. 7, 8) a small body, evidently composed of two angular rods, was found outside of the nucleus; this may be an early stage of the centrioles. Through the maturation period acidophile bodies of variable occurrence and size occur in the cytoplasm and within the spindles, and are shown upon the drawings by light shading; whether these are chromophilic corpuscles or portions of plasmosomes, or both, was not determined. Not a trace of an idiosome was found.

B. DISCUSSION.

Nothing of importance has been written on the growth period of the spermatocytes, except that Gutherz (1911) could distinguish allosomes at this time (cf. his footnote, p. 255). The number of chromosomes in human primary spermatocytes was computed to be 8 by Bardeleben (1892, 1897, 1898), to be apparently 18 by Wilcox (1900), to be 12 by Duesberg (1906) and Guyer (1910). I can confirm Guyer's conclusion that there are 12, of which 10 are bivalent gemini, each dividing in both maturation mitoses, and 2 are univalent allosomes (accessory chromosomes) which divide only once in the two maturation mitoses. Guyer's view is therefore probably correct that the number in the spermatogonia must be 22, and not 24 as reasoned by Duesberg.[2]

But Guyer concluded that the two allosomes always pass undivided to one spindle pole in the primary spermatocytes, reaching then only half of the secondary spermatocytes, and in these dividing presumably equationally. He consequently argued two classes of spermatozoa are produced in equal numbers, one class containing division products of both allosomes, the other class lacking these. That is to say, he overlooked the variability in behavior of the allosomes specially studied by me.

Before discussing this variability we will decide whether it should be regarded as a normal or a pathological process. Is it only a pathological peculiarity of

[2] The papers of Branca were not accessible to me.

the individual testis studied by me? This can certainly not be the case. For the man was a healthy one, the cells exhibiting varieties appeared in all respects normal in structure so far as details of the spindle and the other chromosomes are concerned. Further, and this is an important matter, no degenerating late stages of spermatocytes or spermatids were found, though we should expect them were a large proportion of cells affected by disease. Again, the number of perfectly normal spermatozoa was very high for exceedingly few cases were found of spermatozoa presenting marked abnormalities. Yet these results alone did not satisfy me, I wished to see the cells of another healthy man, and therefore wrote Prof. Guyer for some material from his specimen. On sections of the material generously furnished by him I found only a small number of first maturation mitoses, not more than 8 satisfactory lateral views; of these there were 7 cases of condition *A*, which he regarded as the regular one, also 1 case of the variation *C*. On his material second maturation mitoses were more numerous, and in 4 of them the variation *e* was found; it will be recalled that condition *e* of the secondary spermatocytes evidently results from condition *C* or *D* in primary spermatocytes. Therefore, two of the variations found in my material were observed also in that of Guyer. Further, attention may be called to Guyer's fig. 7, which he states "shows also two precociously diverging daughter chromosomes." It appears to me this might be interpreted as a case of variation *C*, with the allosome *D* at the upper pole, and a half of *d* at that pole and the other half at the lower pole.

Consequently we are justified in concluding the variations observed, at least of the allosomes, to be quite normal phenomena.

We may now summarize the allosome behavior in the primary spermatocytes with respect to their distribution to the secondary spermatocytes, and from this infer their distribution to the spermatids, using the letters *D* and *d* to denote the larger and smaller allosome, respectively. In so doing we should recall that each allosome divides only once in the course of the two maturation mitoses, and undergoes one transport (reductional) without division.

Condition A. 59 cases. Both *D* and *d* at one spindle pole. Both would then go to one secondary spermatocyte and in that one divide equationally. 118 spermatids would then each contain $\frac{1}{2}D$ and $\frac{1}{2}d$, while 118 would receive no part of these. This is the most usual condition and the one discovered by Guyer.

Condition B. 5 cases. *D* at one spindle pole, *d* at the opposite pole. One secondary spermatocyte would receive *D* entire, and the other *d* entire. These dividing in the secondary spermatocytes would result in 10 spermatids each with $\frac{1}{2}D$, and 10 each with $\frac{1}{2}d$.

Condition C. 10 cases. *D* at one spindle pole, $\frac{1}{2}d$ at that pole and $\frac{1}{2}d$ at the opposite pole. Half the secondary spermatocytes would receive only $\frac{1}{2}d$, which does not divide again, consequently from this line would result 10 spermatids with $\frac{1}{2}d$, and 10 with no allosome. The remaining secondary spermatocytes would receive *D* and $\frac{1}{2}d$; the former would divide in them but not the latter, and there would result 10 spermatids with $\frac{1}{2}D$ and 10 with $\frac{1}{2}D$ and $\frac{1}{2}d$.

Condition D. 5 cases. *D* probably dividing at the equator (for it is absent at the poles), *d* at one spindle pole. Half the secondary spermatocytes would receive *d* and ½*D*; in them *d* would divide but not ½*D*, and there would be formed 5 spermatids with ½*d*, and 5 with ½*d* and ½*D*. The other secondary spermatocytes would receive only ½*D*, which would not divide in them, consequently 5 spermatids would receive ½*D* and 5 would receive none.

Condition E. 3 cases. Both *D* and *d* dividing in the equator. Every secondary spermatocyte would then receive ½*D* and ½*d*, and these would not divide again. It would then be a matter of chance how these allosomes became distributed to the spermatids. There might be: either 6 spermatids with ½*D* and 6 with ½*d*; or 6 spermatids with ½*D* and ½*d*, and 6 spermatids with no allosomes.

Summarizing from the above the inferred distribution of the allosomes to the spermatids, but omitting condition *E* because it presents alternatives, we would find:

133 spermatids with	½*D* + ½*d*	=	42.09 per cent.
133 spermatids without	½*D* + ½*d*	=	42.09 per cent.
25 spermatids with	½*D*	=	7.91 per cent.
25 spermatids with	½*d*	=	7.91 per cent.

That is, 42.09 per cent. of the spermatids contain 2 allosomes, the same number contain no allosomes, and 15.82 per cent. contain 1 allosome.

With respect to allosome content there would, accordingly, be four classes of spermatozoa, and not simply the two classes distinguished by Guyer.

Our study on the variations of the second maturation division confirms these conclusions. From the arrangement of the allosomes in this mitosis, however, we may conclude still a larger number of classes of spermatids or spermatozoa.

In *condition c*, 1 case, a small chromosome, probably *d*, containing a split, lay nearer one spindle pole. Should it pass undivided to that pole, that spermatid would receive the whole of *d*. In *condition f* three small chromosomes were found at one spindle pole, one of which may be ½*D*, each of the others at ½*d*; the spermatid receiving these would then get ½*D* and all of *d*.

To the four classes of spermatids or spermatozoa already described, there are, accordingly, possibly two others to be added: spermatids containing the whole of *d*, and spermatids containing this and also ½*D*.

There are then in man certainly four classes of spermatozoa with regard to their allosome content, and possibly five or six. Scarcely any of the spermatozoa examined show abnormalities and no degenerating ones were found, therefore there is no reason to believe that all but certain classes of sperm degenerate or prove incapable of fertilization. We have seen that the mature sperm differs merely in volume by graded variation.

Guyer reasoned that spermatozoa with two allosomes on entering an egg would give rise to females, and that those without allosomes on fertilizing eggs would produce males; "in the light of these facts we should expect the somatic cells

of man to contain twenty-two, and of woman, twenty-four chromosomes," in parallel to the conditions found by Wilson (1909) in the hemipteron *Syromastes*.

It is hazardous to attempt to solve this problem at present for we understand only one side of the equation, and know nothing of the chromosome relations in the human female. But it may be a long period before we secure for study maturation and fertilization stages of the human egg, so that a preliminary working hypothesis may be permitted. This hypothesis must account not only for the two classes of spermatozoa recognized by Guyer, but also for the two additional classes found by me. There is reason to believe all four classes of spermatozoa are capable of fertilization, because all have similar structure and no evidence was found of any kind of them degenerating.

The primary spermatocytes contain both *D* and *d*, and so far as we know this combination only. The primary oöcytes might be supposed to contain any of the following combinations: *d*, *d*, or *D*, *d*, or *D*, *D*, or *D*, *D*, *d*, *d*. But the first two of these combinations cannot occur because we know that in other animals the allosome mass of primary oöcytes is always greater than that of primary spermatocytes. Also the third possible combination cannot occur, for then the mature egg would contain simply *D*, a smaller mass than certain spermatids contain.

Therefore the best explanation of the probable relations in the oögenesis is that given by Guyer, that the primary oöcytes contain *D*, *D*, *d*, *d*, and each mature egg, *D*, *d*. Then fertilization by the four classes of sperm would result as follows:

(*a*) Egg with *D*, *d* × Sperm without *D*, *d* = *D*, *d* (♂).
(*b*) Egg with *D*, *d* × Sperm with *D*, *d* = *D*, *D*, *d*, *d* (♀).
(*c*) Egg with *D*, *d* × Sperm with *D* = *D*, *D*, *d* (♀).
(*d*) Egg with *D*, *d* × Sperm with *d* = *D*, *d*, *d* (♀).

The primary spermatocytes of both male individuals so far described have the allosomes *D* and *d*, and no other combination; therefore fertilization of the type (*a*) should result in males and the other fertilization types in females.

In the female individual resulting from fertilization of type (*b*), it is to be presumed that *D* would conjugate with *D* and *d* with *d*, the bivalents then undergo a reduction division, and the mature eggs contain *D* and *d*.

In the female individuals resulting from fertilization of types (*c*) and (*d*) there might be two possibilities: (1) Such individuals might not develop, but perish. But there would seem to be no good reason for such an assumption. Or (2) (and this result would seem more probable), these individuals also would contain *D* and *d* in their mature eggs, provided that in them the unmated (unpaired) allosome, whether *D* or *d*, remains within the egg and is not discharged entirely into a polar body. There is some basis by analogy for this assumption, for Morgan (1909) found that in the male-producing eggs of phylloxerans two entire allosomes always pass into the polar body; there might then be in the human egg some mechanism by which an unpaired allosome is retained within the mature egg.

Such reasoning would account satisfactorily for the number of allosomes found in human males, as well as for the postulate that all four classes of spermatozoa are capable of fertilization. But if it be correct it would not explain the numerical sex ratio in man, where the males are more numerous than the females. For if three of the four classes of spermatozoa are female-producing, there should be more females than males. Also if there be only two classes of sperm capable of fertilization, as Guyer argues, and one kind of egg, this should result in equal numbers of the sexes and not in the ratio actually known.[3]

This analysis seems to be as far as we can go at present, yet it is entirely speculative and unsatisfactory because we understand nothing of the chromosomal relations in the female. It, however, does indicate strongly one important conclusion, that in man the male is heterozygous, the female, homozygous.

What appears to be of much more importance is the establishment of the fact of real intra-individual germinal variation. This variation in the spermatocytes concerns principally the two allosomes, in lesser degree the ordinary chromosomes. Instead of reasoning deductively that such variation must occur, the actual evidence of its occurrence is increasing, and such phenomena will in time furnish the basis of our understanding of variation.

A second important point needs mention. Bardeleben held that a second reduction of the chromosomes occurs in the secondary spermatocytes, resulting in approximately a quarter of the normal number in the spermatids. Guyer found about the same result, concluding of the secondary spermatocytes that "half of them show five and the remainder seven chromosomes. A second pairing of the ordinary chromosomes has evidently occurred, so that there are five bivalent chromosomes in each type of cell and the additional two accessories in the one type." I have seen no evidence of any kind of such a pairing of chromosomes in the secondary spermatocytes, neither in my own material nor in that received from Guyer, though I have examined fully two hundred division stages of these cells. Of decisive value are such cases, of which several are figured by me, where all the chromosomes can be distinctly seen on lateral views of spindles of the second maturation. The only explanation I can offer for this conflict of opinion is that Bardeleben and Guyer either employed too intense staining of their sections, or else studied cells in which the chromosomes had been greatly swollen by fixation and hence were not clearly distinguishable. In fact, those fixed by Zenker's fluid appeared far more distinct and separate than those preserved in either Bouin's or Gilson's fluid.

[3] Attention may be again called to the fact that in a number of species of animals males and females do not occur in equal numbers, yet equal numbers should result if the allosomes alone are sex determinants.

II. Spermiogenesis.

A. observations.

1. *Nuclear Changes and Formation of the Cuff.*

Figs. 56–58, Pl. III, exhibit the early rounded nuclei of spermatids, in which there are to be seen irregular masses attached to the reticulum. These were drawn from iron-hæmatoxylin stains, by which plasmosomes cannot be satisfactorily distinguished. But with the use of the Ehrlich-Biondi stain a single red-staining plasmosome may generally be distinguished near the center of the nucleus, and sometimes one or more densely green bodies, which lie usually against the nuclear membrane; the latter may be either allosomes or karyosomes, I have not attempted to decide which.[4]

Then follows an elongation of the nucleus (figs. 59–61) in the direction of the centrosomes. This is immediately followed by a retraction of the nuclear wall near the centrosome pole, whereby at that point the nucleus becomes concave, and just at that concavity appears a drop of fluid in the cytoplasm. This drop (*Co*, figs. 62, 63) is the first appearance of the substance of the cuff; it has been represented on this and succeeding figures by dark shading simply to make the drawing more distinct, but in the preparation it appears lighter than the cytoplasm. Its appearance simultaneously with the shrinkage of the nucleus, which from now on, decreasing in volume becomes gradually more dense, proves that it is discharged karyolymph. The nuclear membrane always seems to be intact opposite the drop, and the drop at first is not sharply bounded on its outer surface. Consequently there can be no doubt of its extra-nuclear position. Shrinkage of the nucleus and enlargement of this cuff substance go hand in hand showing that the two are dependent phenomena.

The nucleus shrinks most markedly in its distal position, which frequently exhibits irregular prolongations (figs. 66, 71), and this portion early becomes dense and loses all nuclear sap as is clearly observable in the succession of stages on Plate III. Most frequently this posterior portion of the nucleus becomes a pointed cone demarcated from the anterior, more rounded portion by a slightly projecting annular girdle that is to be seen in most of the figures. But the posterior portion offers a great variety of forms during the spermiogenesis, due in part to the angle from which the nucleus is viewed, in part, also to variation in method of condensation. Great lengthening of the posterior portion is quite frequent, such as shown in figs. 70, 73, 74, 75, 83, 85. The process of discharge of karyolymph from the nucleus continues until the posterior portion of the latter becomes quite dense, while the anterior portion never loses all of its karyolymph but always retains one or more droplets of it. Thus though the two regions of the nucleus are readily distinguishable they differ mainly in that the posterior region discharges all its karyolymph and so undergoes the greater shrinkage.

[4] Guyer's fig. 18 showing two spermatids "one without chromatin nucleoli, the other with two" was drawn after iron-hæmatoxyline staining, and therefore does not prove these bodies to be allosomes.

The anterior region appears lighter because of some flattening, but especially because it retains some droplets of karyolymph.

During the spermiogenesis it seems to be impossible to distinguish the allosomes.

The karyolymph discharged from the nucleus composes at first a mass at or near the posterior region of the nucleus (figs. 62, 63). This increases in amount gradually, probably by further discharge from the nucleus, and its lateral contours come to be bounded by a definite membrane (fig. 64 and the following). It then comes to encompass more or less of the posterior region of the nucleus, never extending forward of the annular girdle, and to extend behind it usually to the distal centrosome (Plate III). At its posterior border it does not appear to be so sharply bounded as laterally, which seems to be due to its changing into a hollow cylinder or cuff open posteriorly (fig. 92); but I could not determine whether all its substance becomes arranged in such a hollow, open cylinder or only its more peripheral denser part. No evidence was found that this cuff is at any time composed of fibrils so as to produce a fibre-basket (Faserkorb). Within this cuff both centrosomes generally lie, though sometimes the cuff does not extend to them (figs. 71, 75, 77, 88). In later stages the cuff usually becomes more indistinct, so that often only traces of its wall are to be seen (figs. 93, 95, 96, Plate III; 103, 104, 106, Plate IV). The irregular bodies found within the cytoplasm in the later stages (figs. 95, 96, Plate III; 97–100, 102, 105, Pl. IV), which are probably comparable with the "tingirbare Körner" of the German writers, may in part at least represent fragments of the cuff substance. But the cuff disappears entirely before the maturity of the spermatozoön, its remnants being thrown off with the abstricting cytoplasm. The latest persisting stages of the cuff are shown in figs. 101, 103, 104, 106, of which the first represents an unusually delayed persistence of it; with the final complete abstriction of the cytoplasm all traces of it become lost.

Thus the greater part, but not quite all, of the karyolymph, leaves the nucleus to compose the cuff substance, which process accounts for the marked shrinkage in nuclear volume; and the final abstriction of the cuff substance from the spermatozoön eliminates the major portion of the karyolymph from the cell.

2. *Centrioles, Flagellum, Cytoplasmic Structures.*

No trace of a sphere was found in the spermatids (nor in the spermatocytes), and no sign of a lance or perforatorium at the anterior end of the spermatozoön.

In the anaphases and telophases of the second maturation mitosis (figs. 53, 55, Pl. III) centrioles could not be discerned, and therefore are probably very minute. They are clearly visible first at the stage of fig. 56, where two of equal size are seen against the cell membrane. The outer one of these remains always the most posterior and will be called the distal centriole (*c.d.*), the inner one will be named the proximal centriole (*c.p.*). From this stage on a delicate but deep staining flagellum is connected with them. Then the proximal centriole

begins to elongate, and to enlarge more rapidly than the distal (figs. 57, 58), whereupon both sink inwards to lie against the nucleus (figs. 59, 60); this movement produces an infundibuliform depression of the cell body out of which the axial filament projects, and this funnel comes later to lie upon one side of the cell (figs. 62–64, 73, 76, 79, 81, 85, 88, 91), and still later to close entirely. The proximal centriole (*c.p.*) becomes angularly bent, with one end touching the distal, while the latter flattens slightly and then becomes a ring (figs. 60–64). Frequently the proximal lies in such a position as to be hidden by the nucleus. (fig. 66), or so as not to show its angular form (figs. 59, 62, 64, 68).

From this time on it will be convenient to follow the two centrioles separately.

The distal centriole is the one that undergoes the fewest changes. It early becomes a small ring with a minute aperture (*c.d.*, fig. 63), and throughout its history appears to remain against the cell membrane. It then increases slowly in size until it attains the diameters shown in figs. 74–91. In one case a granule was observed just distal from it (fig. 82), but whether derived from it I could not ascertain. All through this long period the distal centriole continues in contact with the proximal, and has a lateral position upon the cell. Later the distal centriole moves away from the proximal, and comes to lie some distance behind the nucleus (figs. 93–96, Pl. III; 97–101, Pl. IV). As it moves caudad it becomes smaller, as seen in figs. 99, 100, and in the latest stage in which it was found, fig. 101, it was a very small, pale-staining body. On no later stages was any trace of it to be observed, so that I cannot say whether it becomes thrown off with the cytoplasm, completely degenerates, or persists, though invisible, in some region of the tail as, *e. g.*, just behind the mitochondrial mantle. Certainly, however, no trace of this centriole is to be observed in the mature spermatozoön.

The proximal centriole has a more complicated history. It retains for a long while the angular form already described (figs. 58–75), whereby one end touches the nucleus. It lies then very close to the distal centriole and may touch it either at the centre or at the periphery; rarely are the two at this time distinctly separated, but when they are (fig. 77) the axial filament can be seen connecting them. Then the proximal centriole begins to change its shape, changing from an angular to a curved and then to a rod-like form (figs. 77–81). It afterwards constricts into a smaller anterior portion (*c.p.*, figs. 82–86) and a larger posterior portion (*c.p.* 2). The anterior portion lies against the nucleus some little distance from its posterior end (figs. 84–86).

In later stages, as a rule, the anterior portion of the proximal centriole cannot be recognized on account of its close apposition to the nucleus; but occasionally it may be discerned projecting slightly from the nucleus (*c.p.* 1, figs. 107, 114, Pl. IV), and in a single case it was observed very distinctly (fig. 115). The posterior portion remains for a while quite large (*c.p.* 2, figs. 88–92), and is connected with the nucleus (or rather with the anterior portion at the nucleus) by a deep staining thread of centrosomal substance. Immediately thereafter the

posterior portion becomes much smaller and moves close to the nucleus (*c.p.* 2, figs. 87, 93–96). Sometimes this portion comes to actually touch the nucleus (fig. 94), but as a rule it remains separated from it by a clear area, the neck. For some time this posterior portion of the proximal centriole remains a distinct, rounded body, though staining faintly (*c.p.* 2, figs. 97, 99, 100, 103, 106, where it should not have been drawn deep black), but in the mature sperm it becomes a narrow line or disc bounding the posterior border of the neck. Thus fig. 101, *c.p.* 2, shows it as a minute spherule, and figs. 105, 107–112, 114 as a dark line at the anterior border of the mitochondrial mantle.

The neck (collum) of the spermatozoön is then the region between the nucleus and the mitochondrial mantle. Its details are seen most distinctly in fig. 115; here the neck is composed of a homogeneous non-staining part between the anterior portion (*c.p.* 1) of the proximal centriole in front, and the posterior part (*c.p.* 2) of this centriole behind. Lying as it does between these two parts, the intermediate clear substance should be considered a differentiation of the original centrodesmosis shown in figs. 82–92, Pl. III. No fibrous structures could be seen within the neck.

The flagellum arises first in the spermatids in connection with the centrioles. The earliest appearance found is shown in fig. 57, Pl. III. It grows rapidly in length, as shown in fig. 59, and none of the other figures of this plate show it in its fullest extent. At first it appears to be connected only with the distal centriole, but when this becomes a ring the flagellum appears to pass through it to join also the proximal centriole (figs. 77, 86). After the proximal centriole has constricted into its two moieties the flagellum is much thicker than before (figs. 90, 93–96), and with the migration of the distal centrosome away from the proximal is clearly seen to extend all the way between the two. When thickened it may be called the axial thread.

The cell body of the spermatid is at first rounded (figs. 56, 57, 59, Pl. III), but in these early stages frequently exhibits slender extensions (figs. 58, 60) which may be movable pseudopodia such as those seen by me (1911) in life in *Euschistus*. Lengthening of the cell body accompanies lengthening of the nucleus (figs. 61–96). Thereby most of the cytoplasm comes to lie behind the nucleus and leaves only a thin mantle around the latter, though no precise regularity is to be observed in these movements. Very frequently the cell membrane becomes indrawn around the annular girdle of the head, so as to make a small mass of cytoplasm around the anterior portion of the head separated from a larger mass around the posterior portion (figs. 74, 76, 77, 81, 92, 93, 96); the cell membrane of the anterior mass usually appears thicker and more refractive. Then follows the abstriction from the spermatozoön of the greater amount of the cytoplasm, various stages of which process are delineated in figs. 72, 76, 88–96, Pl. III; 98–106, 114, Pl. IV). During this abstriction darkly-stained granules and threads appear in the cytoplasm, probably derived in part from the degenerating cuff. All the cytoplasm does not generally fall off in a single piece, but

more frequently in several fragments as indicated in figs. 90, 99, 102, and usually the anterior region of the head is the first to become freed from it. Many of the spermatozoa within the epididymis still possess masses of cytoplasm, and occasionally some of those in the vas deferens. In the fully matured spermatozoön (fig. 109) the only cytoplasm would seem to be enveloped around the chondrial mantle. The abstricted cytoplasmic masses are easily recognized within the lumen of the seminiferous tubules and in the epididymis.

There remains to be noted only the mitochondrial mantle. In the spermatocytes and spermatids no mitochondria are observable, and they had probably been dissolved by the fixatives. In fig. 98, Pl. IV, is represented an abnormal immature spermatozoön with two axial filaments, and around each of the latter an irregular coil of dark-staining substance (*Mit.*) that seems to be an early stage of the mitochondrial mantle. It is to be noted that while these exhibit a certain spiral disposition, there is no indication that each is a continuous spiral. The mitochondrial mantle of the mature spermatozoa (*Mit.*, figs. 109–112, 114, 115) is of variable length, but always longer than the head, lies immediately behind the neck, and generally appears as a dense mass without differentiation. But in one case (fig. 107) it was clearly seen to compose a hollow cylinder around the axial filament and to show a somewhat granular structure.

3. *The Ripe Spermatozoa.*

These are shown in figs. 107–115, from the vas deferens (figs. 108, 110, 111, seen from edge) and their structure has been elucidated by the preceding account of their histogenesis. The head is composed of two parts, sometimes (rather rarely) demarcated by slight annular girdle or groove; an anterior part which contains one or several droplets of karyolymph, and which appears lighter by reason of its being more flattened; and a posterior thicker part that is entirely dense. Next follows the anterior portion (fig. 115, *c.p.*) of the proximal centriole, the clear region of the neck, the posterior portion of the proximal centriole (*c.p.* 2), the mitochondrial mantle (*Mit.*), the principal part of the tail, and finally the terminal filament (figs. 109, 114). No trace of the distal (ring) centriole can be found, and frequently the parts of the proximal centriole are not apparent. No cytoplasm was observable in the head and neck region; in in the remainder it forms a mesh within and around the mitochondrial mantle (fig. 107). It could not be observed that the mitochondrial mantle composes a spiral thread.

The heads of the mature sperm from the vas deferens vary remarkably in volume, and figs. 113 and 112 show the largest and smallest found. To determine the nature of this variation the heads of 100 mature spermatozoa, chosen at random, were carefully drawn to the same scale, the precaution being taken to draw only such as lay exactly in the plane of the section. The drawings were then measured in millimeters, and showed a range in length of the heads from 10 mm. to 27 mm. Plotting the measurements according to size they are seen

to exhibit graded variations in a regular curve, the mean being from 15 to 15.9 mm., and 86 per cent. falling between 13 and 18.9 mm. Therefore, although there is a remarkable range of volume, it is continuous variation around the mean, and the spermatozoa cannot be arranged into two or more size classes.

B. DISCUSSION.

Of the numerous accounts of mature human spermatozoa since their first description by Leeuwenhoek (1677), may be specially mentioned those of Jensen (1887), Broman (1902), Ballowitz (1891), Retzius (1902, 1909, 1910), and the diagrammatic figures given by Meves in the work by Waldeyer (1906). Broman's descriptions treat to great extent abnormal spermatozoa, a subject upon which we shall not enter, and he described a spiral thread around the middle piece; that the mitochondrial substance composes a spiral thread has been strongly denied by Retzius. Prenant (1888) also found a spiral thread, and believed it terminates posteriorly in a distal centriole ("bouton intercaudal"). Meves' figures show a somewhat greater complication in the region of the middle piece than I have been able to determine. By the use of isotonic solutions Koltzoff (1908) found the entire sperm enveloped by a semipermeable membrane, a structure not seen by other writers. Retzius (1909) found the most anterior centrosome (our anterior portion of the proximal centrosome) to consist quite regularly of two granules.

The idea I have formed of the structure of the human spermatozoön in its mature condition is represented in the diagrammatic figure 16, Pl. IV. Applying the new terminology of Waldeyer it is seen to be composed of the following main parts: the caput or head (*Cp.*), the collum or neck (*Cl.*), and the cauda or tail (*Cd.*). The head consists of a pars anterior (*P.A.*) which alone contains a few droplets of karyolymph (these quite variable in number and size), and of a pars posterior (*P.p.*); only occasionally does a groove demarcate the two. The neck consists of an anterior nodulus (*Nd.A.*), the anterior portion of the proximal centriole; a posterior nodulus (*Nd.P.*), the posterior portion of the proximal centriole; and of a structureless, non-staining intermediate mass (*M.Int.*). The tail is composed of a junction piece (pars conjunctionis, *P.C.*), a pars principalis (*P.Pr.*), and the terminal filament (pars terminalis, *P.T.*); the axial thread (*Ax.F.*) extends throughout the tail. Within the junction piece lie the mitochondrial granules, these making a mantle and not a spiral thread around the axial thread. Cytoplasm (*Cyt.*) seems to be limited to the junction piece.

On the histogenesis, however, but little has been done. Bardeleben in a series of papers, of which those of 1897 and 1898 are the most important, made known a series of stages illustrated for the most part by unclear small figures. However, he pointed out the great shrinkage of the nucleus, with the ejection from it of a drop of karyolymph ("Arginkörper"), but believed this to furnish the drops in the head region. He also described the cuff, the division of the proximal centriole, and held the mitochondrial sheath to be formed from the

nuclear membrane. Meves (1897) was the first to describe early spermatids with a pair of centrioles on the surface, and the flagellum connected with these; later (1898), in another brief paper, he stated that the proximal centriole comes to lie just behind the head, while the distal one, before becoming a ring, buds off a little rod. I have paid particular attention to this last point, but have found no division of the distal centriole. Broman (1901) figured clearly the centrioles and cuff, and certain complex spherical bodies ("Korbbläschen") that he holds are not homologous with mitochondria because there is no trace of them in the spermatocytes and because they disappear before maturity. Retzius (1909) has given the best figures of the later stages of the spermiogenesis but the accompanying description omits many of the interesting details shown in the plates. He finds the mitochondrial mantle is derived from certain large granules, six to seven in number, on each side of the middle piece; that the cuff is an open cylinder and at no period fibrous; and that a great lobe of cytoplasm abstricts. His figures also show that not only the anterior portion of the proximal centriole may consist of two or three parts, but also the posterior portion of the same centriole. Retzius' is the most important study, but it would have much more value had he seriated the stages figured.

An important side of any study of spermiogenesis is to determine just what parts and substances contribute to the mature spermatozoön, and, accordingly, to the fertilization of the egg. It is now established for a considerable number of cases that the entire spermatozoön enters the egg, without omission of the tail. But it is also known that in most cases only a portion of the spermatid contributes to the spermatozoön. Thus in man as in most animals, with the possible exception of amphibians and some insects, the greater part of the cytoplasm becomes abstricted and cast away. And that happens in man also with the greater amount of the karyolymph, which we have described as being forced out of the nucleus to produce the cuff substance which is later thrown off with the cytoplasm. Meves (1899), Duesberg (1908) and others generally hold that the cuff is a cytoplasmic differentiation, but Van Mollé (1905, 1910) found that the cuff is derived from achromatic nuclear material, and my present account agrees with his, except that I do not find the cuff is formed by buds off the nucleus, but rather from a discharge of nuclear sap through the nuclear membrane. This explanation of the genesis of the cuff coincidentally explains the sudden shrinkage of the nucleus, and I have called attention (1911a) to the fact that this shrinkage is a very general phenomenon. The spermatozoön then loses the greater part of both cytoplasm and karyolymph, for which reason these substances can play little part in inheritance.

Another interesting matter concerns the history of the centrioles. These become large and very distinct about the middle period of histogenesis, near its close they lose their staining power and become suddenly much smaller. No trace of the distal one can be found in the mature sperm. In *Euschistus* it was described by me (1911a) how at a certain period both centrioles seem to suddenly

vanish from view. It is also to be recalled that in the fertilized egg never more than one aster with one centriole arises close to the sperm head. Therefore it would seem probable that the elaborate changes of the centrioles in the spermiogenesis are concerned chiefly with the formation of the axial filament and changes in form of the cell, and that when these changes are accomplished all but one of the centrioles degenerate.

Lastly, attention may be drawn to the great range in volume of the heads of normal spermatozoa, already remarked by Retzius, and found by me to be a case of graded variation (fluctuation). The mass of chromatin introduced by the sperm into the egg may well have causal connection with the variation in the somatic persons. The sizes of the spermatozoön heads offer a clear case of germinal variation of graded character; the variation of behavior of the allosomes in the maturation divisions would represent discontinuous variation.

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EXPLANATION OF PLATES I–IV.

All figures have been drawn by the author to the same scale at the level of the base of the microscope, with the aid of a camera lucida; Zeiss apochromatic homogeneous immersion 1.5 mm., ocular 12, tube length 160 mm., a magnification of × 3500. All cells figured are from one testis fixed in Zenker's fluid, with the exception of fig. 107 from a testis fixed in Bouin's fluid.

The following abbreviations are employed:

C.d., distal centriole.
Co., cuff.
C.p., proximal centriole.
C.p. 1, anterior moiety of the same.
C.p. 2, posterior moiety of the same.
D, larger allosome.
$D\frac{1}{2}$, one-half of the same.
d, smaller allosome.
$d\frac{1}{2}$, one-half of the same.
G, a geminus or bivalent ordinary chromosome.
$G\frac{1}{2}$, a dyad or half of the preceding.
Mit., mitochondrial sheath.
P., plasmosome.

PLATE I.

FIG. 1. Strepsinema stage of a giant spermatocyte.
FIGS. 2–6. Strepsinema stages.
FIGS. 7–12. Late prophases of first maturation division.
FIG. 13. Polar view of chromosomal plate of first maturation division, condition *A*; the allosomes at a different level from the other chromosomes.
FIG. 14–17. Lateral views of first maturation division, condition *A*. Fig. 14 shows all 12 chromosomes.
FIG. 18. First maturation division, condition *B*.
FIGS. 19–22. First maturation division, condition *C*; all the chromosomes shown in figs. 19, 21.
FIG. 23. First maturation division, condition *D*.
FIGS. 24, 25. Oblique lateral views of first maturation division, condition *E*.

PLATE II.

FIG. 26. First maturation division, condition *F*.
FIG. 27. First maturation division, the left hand cell shows conditions *A*+*G*, the right hand cell, conditions *E*+*G*.
FIG. 28. Anaphase of first maturation division.
FIGS. 29–31. Telophases of first maturation division.
FIGS. 32, 33. Secondary spermatocytes, stage of interkinesis.
FIGS. 34–36. Late prophases of second maturation division, in each case all the chromosomes are shown.
FIGS. 37, 38. Polar views of second maturation division, all the chromosomes shown.
FIGS. 39–41. Second maturation division, condition *a*; in figs. 39, 40 all the chromosomes are shown.
FIG. 42. Second maturation division, condition *b*.
FIG. 43. Second maturation division, condition *c*, all the chromosomes shown.
FIG. 44. Second maturation division, condition *d*, the chromosomes densely crowded.
FIGS. 45, 46. Second maturation division, condition *e*, both spindles oblique.
FIG. 47. Second maturation division, condition *f*.
FIG. 48. Second maturation division, condition *g*.
FIG. 49. Second maturation division, condition *h*, 1.

PLATE III.

FIG. 50. Second maturation division, condition *h*, 2.
FIG. 51. Second maturation division, condition *h*, 3.
FIG. 52. Second maturation division, condition *h*, 4.
FIG. 53. Anaphase of the second maturation division.
FIGS. 54, 55. Telophases of second maturation division.
FIGS. 57–96. Successive stages in the histogenesis of the sperm, all from the testis; in figs. 82, 83 only the nuclei, centrioles and axial thread are drawn.

PLATE IV.

FIGS. 97–104. Later stages in the histogenesis of the sperm, all from the testis; the full length of the flagellum is shown only in fig. 97.
FIGS. 105–115. Spermatozoa from the vas deferens, the full length of the flagellum shown only in figs. 109, 114.
FIG. 116. Diagram of the human spermatozoon, reconstructed especially from figs. 107, 115. *Ax.F*, axial filament; *Cd*, tail (cauda); *Cl*, neck (collum); *Cp*, head (caput); *Cyt*, cytoplasm; *M.Int*, intermediate substance of the neck; *Mit*, mitochondria; *Nd.A*, anterior nodulus of neck; *Nd.P*, posterior nodulus of neck; *P.a*, anterior portion of head; *P.C*, junction piece (pars conjunctionis); *P.p*, posterior portion of head; *P.Pr*, principal portion of the tail; *P.* 7, terminal filament.

PLATE I.

FIG. 1. Strepsinema stage of a giant spermatocyte.

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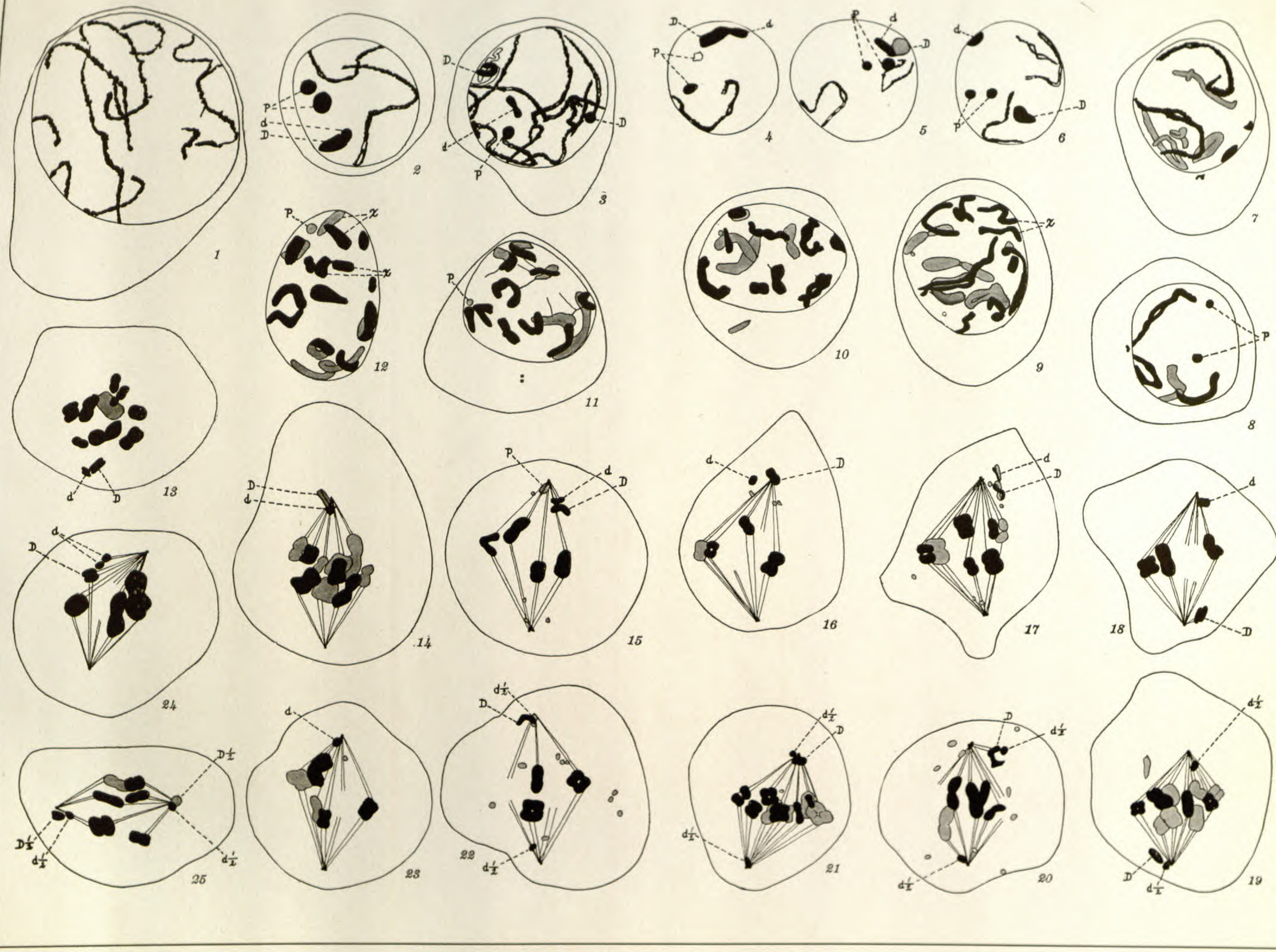
FIG. 23. First maturation division, condition *D*.

FIGS. 24, 25. Oblique lateral views of first maturation division, condition *E*.



MONTGOMERY: SPERMATOGENESIS

PLATE II.

FIG. 26. First maturation division, condition *F*.

FIG. 27. First maturation division, the left hand cell shows conditions $A + G$, the right hand cell, conditions $E + G$.

FIG. 28. Anaphase of first maturation division.

FIGS. 29–31. Telophases of first maturation division.

FIGS. 32, 33. Secondary spermatocytes, stage of interkinesis.

FIGS. 34–36. Late prophases of second maturation division, in each case all the chromosomes are shown.

FIGS. 37, 38. Polar views of second maturation division, all the chromosomes shown.

FIGS. 39–41. Second maturation division, condition *a*; in figs. 39, 40 all the chromosomes are shown.

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FIG. 43. Second maturation division, condition *c*, all the chromosomes shown.

FIG. 44. Second maturation division, condition *d*, the chromosomes densely crowded.

FIGS. 45, 46. Second maturation division, condition *e*, both spindles oblique.

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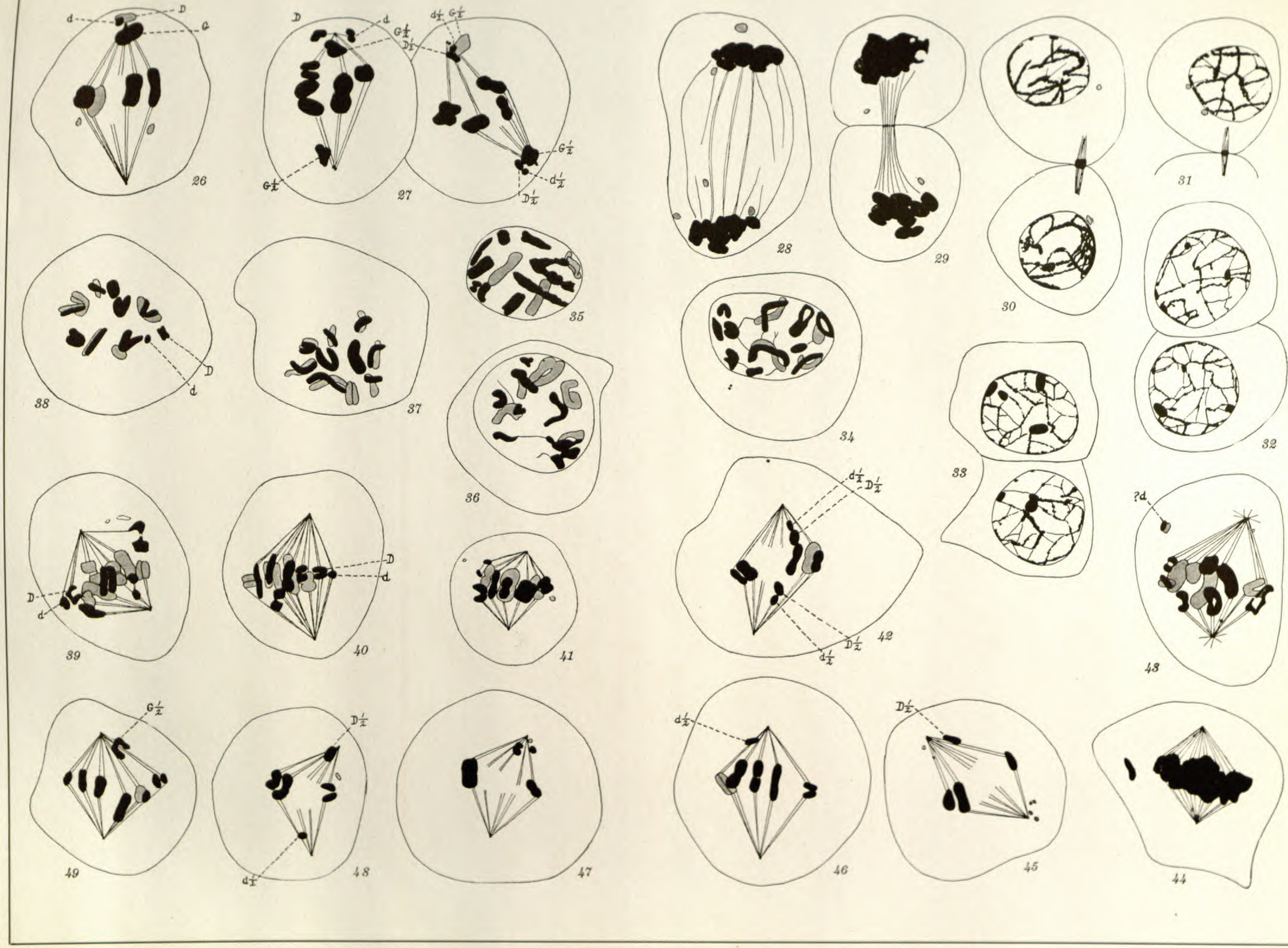
FIG. 48. Second maturation division, condition *g*.

FIG. 49. Second maturation division, condition *h*, 1.



MONTGOMERY: SPERMATOGENESIS

PLATE III.

FIG. 50. Second maturation division, condition *h*, 2.
FIG. 51. Second maturation division, condition *h*, 3.
FIG. 52. Second maturation division, condition *h*, 4.
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FIGS. 54, 55. Telophases of second maturation division.
FIGS. 57–96. Successive stages in the histogenesis of the sperm, all from the testis; in figs. 82, 83 only the nuclei, centrioles and axial thread are drawn.

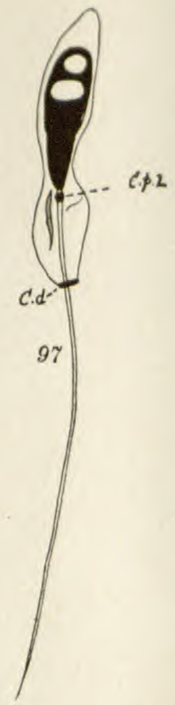
MONTGOMERY: SPERMATOGENESIS

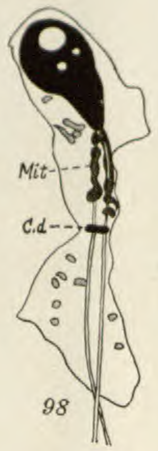
PLATE IV.

FIGS. 97–104. Later stages in the histogenesis of the sperm, all from the testis; the full length of the flagellum is shown only in fig. 97.

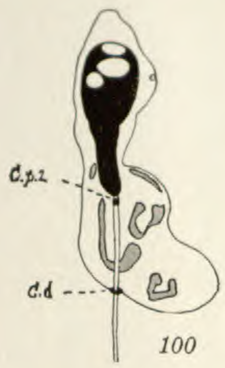
FIGS. 105–115. Spermatozoa from the vas deferens, the full length of the flagellum shown only in figs. 109, 114.

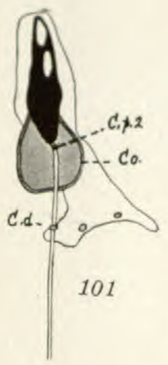
FIG. 116. Diagram of the human spermatozoon, reconstructed especially from figs. 107, 115. *Ax.F*, axial filament; *Cd*, tail (cauda); *Cl*, neck (collum); *Cp*, head (caput); *Cyt*, cytoplasm; *M.Int*, intermediate substance of the neck; *Mit*, mitochondria; *Nd.A*, anterior nodulus of neck; *Nd.P*, posterior nodulus of neck; *P.a*, anterior portion of head; *P.C*, junction piece (pars conjunctionis); *P.p*, posterior portion of head; *P.Pr*, principal portion of the tail; *P.7*, terminal filament.


C.p.2
C.d
97

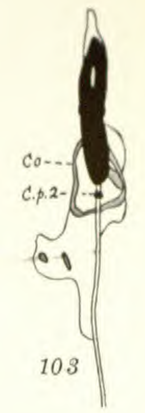

Mit
C.d
98

C.p.2
99
C.d

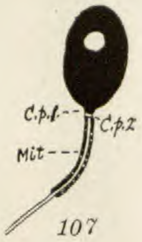

C.p.2
C.d
100

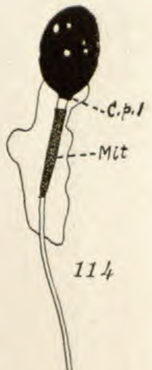

C.p.2
Co.
C.d
101

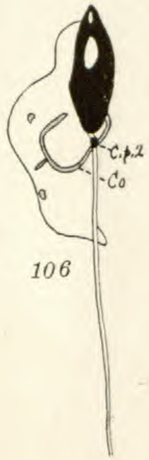
102


Co
C.p.2
103

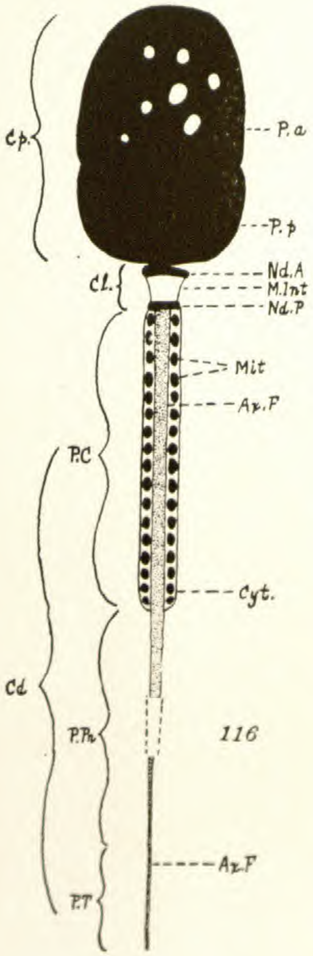
104
Co.


C.p.1
C.p.2
Mit
107


C.p.1
Mit
114

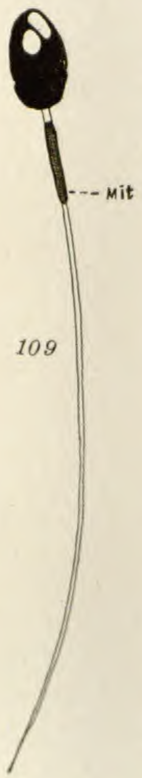

C.p.2
Co
106

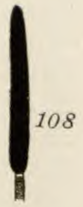
Mit
105


C.p.
P.a
P.p
Cl.
Nd.A
M.Int
Nd.P
Mit
Ax.F
P.C
Cyt.
Cd
P.P.
116
Ax.F
P.T

Mit
111

Mit
110


Mit
109


108

113

C.p.1
C.p.2
Mit
115

Mit
112

A Contribution to the Paleontology of Trinidad

BY

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PLATES V–XIII

PHILADELPHIA
1912

A CONTRIBUTION TO THE PALEONTOLOGY OF TRINIDAD.

By Carlotta Joaquina Maury, Ph.D.

The material described in the following pages was obtained by a geological expedition in charge of Mr. A. C. Veatch, the writer being the paleontologist.

The expedition was carried on under the auspices of the General Asphalt Company of Philadelphia. Opportunity to publish is due to the courtesy of Mr. Arthur Sewall, and Mr. John M. Mack, the present and former presidents of the above company, to whom science is thus indebted for this contribution.

The types have been deposited in the Museum of Cornell University as the gift of Mr. Mack.

The exquisite drawings which illustrate this report are of special value, as they were made by one who is not only an artist but also an eminent paleontologist, Professor G. D. Harris.

Many thanks are due to Dr. Dall, of the United States National Museum; Dr. Stanton, of the United States Geological Survey; Professor G. D. Harris, of Cornell University, and Dr. Rufus M. Bagg for their valuable suggestions.

The specimens were collected from Tertiary beds at Brighton, on the Island of Trinidad, and from the small outlying islets, Soldado and Farallon Rocks. A few are also included from Cretaceous shales and Pleistocene raised beaches,—both on the opposite Venezuelan mainland.

Paleontogically the Tertiary faunas proved very interesting because never before have true basal Eocene beds been found in the Antillean region.

Stratigraphically these faunas were most important because they form a perfect link between the Alabama Midway Eocene and the Pernambuco beds of Brazil, the age of which has hitherto not been determined.

For descriptions of the fossiliferous horizons of Trinidad other than those described in the following pages the reader is referred to the publications of Dr. R. J. Lechmere Guppy, of Port of Spain, Trinidad. Dr. Guppy has for forty-nine years investigated and reported upon the fossil faunas of Trinidad, Jamaica, Tobago, Antigua, and other Antillean islands, and is still contributing able and valuable articles on both the paleontology and stratigraphy of the islands.

OLIGOCENE FOSSILS FROM TRINIDAD.

On the shore near the pier at Brighton are several small exposures of asphalt filled with shells. The two most important of these are respectively 700 feet east and 1000 feet west of the pier. The eastern exposure is an irregular mass much washed by the waves, the western appears to show a distinct northward dip; but on account of the unstable character of the asphalt not much dependence

can be placed on this, particularly as it is in the direction in which the asphalt would naturally flow. Other and clearly recent flows of asphalt contain no shells.

The following species were collected by Mr. Veatch from the outcrop 1000 feet west of the pier:

Arca (*Noetia*) *sheldoniana* n. sp.
Cardium (*Trigoniocardia*) *carolinæ* n. sp.
Pitaria (*Lamelliconcha*) *circinata* Born.
Pitaria (*Lamelliconcha*) *labreana* n. sp.
Chione veatchiana n. sp.
Chione dalliana n. sp.
Mactra austeniana n. sp.
Corbula (*Cuneocorbula*) *helenæ* n. sp.
Corbula (*Bothrocorbula*) *smithiana* n. sp.
Marginella dalliana n. sp.

The locality 700 feet east yielded the following:

Arca (*Argina*) *billingsiana* n. sp.
Arca (*Argina*) *brightonensis* n. sp.
Chione guppyana n. sp.
Pholas mackiana n. sp.
Columbella labreana n. sp.
Columbella asphaltoda n. sp.
Cymia woodii Gabb.
Cerithium harrisii n. sp.
Cerithium isabellæ n. sp.

A glance at these lists shows that all the species are new except two—*Pitaria circinata* Born and *Cymia woodii* Gabb. Fortunately, both these are most significant because of their remarkable distribution. The genus *Cymia* is entirely extinct now on the east coast of the Americas but is living on the west coast of Central America, where *C. tectum*, a species very closely allied to the fossil form, is common. The genus spread westward from an Antillean center of development. The parent stock was exterminated by disturbances following the rise of the isthmus and the western colony alone survived, continuing to the present day.

The presence of *Pitaria circinata* harmonizes with this. As is well known, very few species of mollusks are living on both the east and west coasts of the Central American region. *Pitaria circinata* is one. It is also found in the Oligocene of the Isthmian beds and of Cumana, Venezuela.

Evidence can also be deduced from several of the new species which agrees fully with that furnished by the two already known. Thus *Arca* (*Noetia*) *sheldoniana* is intermediate between the east coast *A. ponderosa* (which it resembles in outline) and the west coast *A. reversa* (which it resembles in the

cardinal area). It also shows a divergence of the west coast species from a common Antillean stock from which it migrated westward before the rise of the isthmus. For this short, high form of *Noetia* is characteristic of the east coast Oligocene. After that period they died out, but the western colonies have continued on to the present.

Mactra austeniana adds a further indication of the Oligocene age of the deposit. Typical Mactras, of which this is one, are not known in America from formations older than the Oligocene.

Pholas mackiana resembles both the recent east coast *P. campechensis* Gmelin and *P. chiloensis* of the Peruvian shores. These species are surprisingly alike, possibly even identical. This fossil *Pholas* from Brighton may well be their common ancestor.

Judging from all the above indications, the age of the shelly asphalt on the Brighton beach is Oligocene—and late Oligocene, perhaps about equivalent to the Chipolan of Florida.

A yellowish-brown ferruginous bed outcrops on the southern main road, just south of Pitch Lake, Brighton, near the 56¾ Mile Post. It is stratigraphically below the asphaltic beds above described and stratigraphically above the large *Ostrea* horizon of the Union Estate, Brighton.

The fossils in the ferruginous bed are all in the form of casts, the original substance of the shells having been wholly dissolved away. The majority could not be determined. A few forms retained some traces of distinguishing characters. These were:

Arca (*Cunearca*) *chemnitzioides* n. sp.
Arca two sp. indet.
Cardita (*Carditamera*) *virginiæ* n. sp.
Corbula sp. indet.
Martesia oligocenica n. sp.
Terebra sp. indet.
Oliva trinidadensis n. sp.
Purpura sp. indet.
Murex cf. *domingensis* Sby.
Calyptræa centralis Con.

The known species, *Calyptræa centralis*, has never been found in strata earlier than the Chipolan of Florida, hence its presence suggests that the bed is not older than late Oligocene.

The fragmental cast of *Murex* may be *domingensis*. If so this also indicates Upper Oligocene. To this the evidence of the most abundant species of the fauna of the ferruginous bed, *Arca* (*Cunearca*) *chemnitzoides*, may be added. Arcas of this type with high umbones and a short, high form are not known below the Oligocene on the southeastern coast of the United States and in the Antilles.

From these evidences the ferruginous bed does not antedate the Upper Oligocene, but is somewhat older than the asphaltic horizon.

One mile west of the Godineau River on the shore of the Gulf of Paria, Mr. Veatch found in a whitish, decayed rock moulds of large shells. These to all appearances are freshwater species. Some are almost certainly Unios; for one specimen shows imprints of the alternating hinge teeth so characteristic of that genus. There is also a large convex shell which might be of the genus *Anodonta* as it has the general form of *A. grandis*.

The occurrence of these freshwater shells recalls the Comparo Road freshwater horizon described by Dr. R. J. Lechmere Guppy and referred by him to the Pliocene. It is more probable, however, that the Godineau River strata are of Oligocene date, but it is impossible to draw any inference as to the true age because of the very imperfect condition of the fossils.

Near San Fernando, Trinidad, is a small outlying island known as Farallon Rock or Johnson's Island. In a light buff-colored or greyish or even blackish non-asphaltic rock on Farallon are Foraminiferal layers with myriads of Orbitoides and Nummulites. The curious crustacean, *Ranina porifera* Woodward, the Helix-like worm tube, *Serpula clymenioides* Guppy, and the urchin, *Echinolampas ovum-serpentis* Guppy also occur.

The horizon is Lower Oligocene and is a continuation off-shore of the San Fernando Orbitoides formation which also contains the *Ranina* and *Serpula*.

EOCENE FOSSILS FROM SOLDADO ROCK.

On Soldado Rock, an islet one hundred and seventeen feet high, lying near the Serpent's Mouth in the Gulf of Paria, just west of the extreme southwest corner of Trinidad, Mr. Veatch found a succession of eight beds of which Nos. 2, 6, and 8 are fossiliferous.

The basal bed, No. 2, is an extremely hard, greyish to reddish limestone containing quantities of shells which have become an integral part of the rock, from which they have fortunately been brought into high relief by the erosive action of the waves that constantly beat upon them.

This bed lithologically is the exact counterpart of Midway Eocene beds near Ripley, Mississippi; Fort Gaines, Georgia; and Clayton, Alabama. Some samples from these various localities and Soldado cannot be distinguished from one another, and this resemblance is still more striking when fragments of rock from these widely separated places contain the same fossils.

The material from bed No. 2 has yielded the following mollusks:

Ostrea crenulimarginata Gabb.
Ostrea cynthiæ n. sp.
Ostrea cf. *percrassa* and *compressirostris* Say.
Ostrea pulaskensis Harris.
Ostrea thalassoklusta n. sp.

Cucullæa harttii Rathbun.
Glycymeris (*Axinea*) *viamediæ* n. sp.
Venericardia alticostata Con.
Venericardia planicosta Lam.
Venericardia thalassoplekta n. sp.
Callista mcgrathiana Rathbun.
Callista mcgrathiana var. *rathbunensis* n. var.
Chione paraensis White var.
Caricella ogilviana n. sp.
Caricella perpinguis n. sp.
Volutilithes pariaensis n. sp.
Lyria wilcoxiana var. *aldrichiana* n. var.
Levifusus pagoda Heilprin.
Fusus colubri n. sp.
Fusus bocaserpentis n. sp.
Fusus meunieri n. sp.
Fusus mohrioides n. sp.
Fusus sewalliana n. sp.
Fusus sirenideditus n. sp.
Clavella harrisii n. sp.
Clavella hubbardanus ? Harris.
Latirus tortilis Whitfield.
Strepsidura ? soldadensis n. sp.
Pseudoliva bocaserpentis n. sp.
Trophon progne ? White.
Cassis togatus var. *soldadensis* n. var.
Cypræa bartlettiana n. sp.
Cypræa vaughani n. sp.
Calyptraphorus velatus var. *compressus* Aldrich.
Veatchia carolinæ n. s. g., n. sp.
Cerithium soldadense n. sp.
Turritella humerosa var. *elicitatoides* n. var.
Turritella mortoni Conrad.
Turritella nerinexa Harris.
Turritella soldadensis n. sp.
Mesalia pumila var. *allentonensis* Aldrich.
Mesalia pumila var. *nettoana* White.
Calyptræa aperta Sol.
Amauropsis caloramans n. sp.

As shown by the above list, this fauna comprises a most interesting mingling of such characteristic North American lower Eocene forms as *Venericardia planicosta*, *Levifusus pagoda*, *Latirus tortilis*, *Calyptraphorus velatus* var. *compressus*

and *Turritella mortoni* with the characteristic Pernambuco forms *Callista mcgrathiana, Chione paraensis, Cucullæa harttii*, etc.

The new species also show strong affinities with basal Eocene (Midwayan) forms from Alabama.

These relationships not only establish the age of the No. 2 bed at Soldado, but also that of the Pernambuco beds as Midway Eocene.

Bed No. 6 contains myriads of Foraminifera, especially Orbitoides, echinoids, and one imperfect Ostrea shell, probably of *O. crenulimarginata*.

Bed No. 8 is an indurated rock noticeable from being stained deep red with hematite and greenish and purplish with other forms of iron.

The following fossils were obtained from bed No. 8:

MOLLUSCA and BRACHIOPODA.

Ostrea golfotristensis n. sp.
Ostrea thirsæ Gabb.
Spondylus sp. indet.
Modiola alabamensis Aldrich.
Venericardia crucedemaionis n. sp.
Meretrix cf. *nuttalliopsis* Heilprin.
Meretrix subimpressa var. *golfotristensis* n. var.
Venerupis atlantica n. sp.
Corbula (*Cuneocorbula*) *subengonata* Dall.
Corbula (*Cuneocorbula*) *weaveri* n. sp.
Cylichna solivaga n. sp.
Pleurotoma guppyana n. sp.
Caricella ? sp. indet.
Volutilithes sp. indet.
Fusus bocarepertus n. sp.
Fusus longiusculoides n. sp.
Fusus tæniensis n. sp.
Fusoficula juvenis Whitf.
Cassis (*Phalium*) *guppyana* n. sp.
Rimella fowleriana n. sp.
Rimella knappiana n. sp.
Cerithiopsis veatchiana n. sp.
Turritella mortoni var.
Solarium stephanephorum n. sp.
Natica cf. *semilunata* Lea var.
Amauropsis smithiana n. sp.
Liotia lillianæ n. sp.
Dentalium microstria Heilp.
Terebratula stantoni n. sp.

One of the most abundant fossils occurring in this bed is the Lignitic species, *Ostrea thirsæ*. The other species also, although mostly new, show a strong relationship to the Lignitic fauna of the Gulf coast of the United States.

In the judgment of Professor Harris this Soldado horizon is about equivalent to the Nanafalayan of Alabama.

COMPARISON OF THE STRATIGRAPHIC EVIDENCE FURNISHED BY THE FORAMINIFERA AND THE MOLLUSCA.

Dr. Rufus Mather Bagg most kindly examined the Foraminifera associated with the molluscan fossils found on Soldado and Farallon Rocks. He was asked particularly to express an opinion as to the geological ages of the deposits in which they were found. Dr. Bagg writes:[1] "The Orbitoidal rock marked bed No. 6, Soldado Rock, is Eocene. I am not sure just what horizon but I note *Orbitoides papyracea* (Boubee); *Orbitoides aspera* Gumbel (*O. faujasii*); and probably *O. mantelli*[2] though I have not access to the literature on the subject. . . . The Soldado bed No. 6 shows a few scattered forms of a typical Cretaceous and early Eocene type which I have never come upon before, namely *Tinoporus vesicularis*, and the more numerous allied species *T. baculatus*. *Tinoporus*,[3] while Cretaceous, is equally developed in the Lower Eocene, where I place your rock.

"The specimen from Farallon Rock is exceedingly interesting, and the entire mass seems to be filled with *Operculina complanata* (Defrance) and is undoubtedly Eocene. It is not usual for this species to assume the rôle of the Eocene Nummulitic or Orbitoidal rock types, and I am glad to identify this interesting Foraminiferum, so characteristic of the early Tertiary formation.

"The argillaceous shale from the Godineau River, Trinidad, was insoluble in the caustic alkalies . . . but I am inclined to think it is of Miocene age, since it is rich in diatoms and it has the rather typical Miocene genus *Coscinodiscus* and a *Pyxidicula*. I sent a small fragment of this to Dr. Edwards of New York, but he said he could not make a slide of it that was of any help in identifying the diatoms."

It is interesting to compare these conclusions of Dr. Bagg with those based on the molluscan fauna by the writer, especially as they were reached wholly independently.

The evidence furnished by both Foraminifera and Mollusca as to the age of the No. 6 bed on Soldado Rock point definitely to Lower Eocene.

The Farallon Rock Foraminifera are, however, also referred by Dr. Bagg to the Eocene. This bed is apparently an outlier off shore in the Gulf of Paria of the San Fernando bed, and the latter contains a molluscan fauna of a decidedly Oligocene aspect. There seems to be no question that the San Fernando and

[1] Letter dated January 30, 1912.

[2] According to Dr. Dall, the West Indian form of *mantelli* is *O. forbesii*.

[3] For illustrations see Carpenter's Introduction to the Foraminifera, Plate XV, Figs. 1, 9.

Farallon beds are the same as they both contain *Ranina porifera*, the very striking species of Crustacea; *Serpula;* and a number of Foraminifera in common. Yet Mr. Veatch from stratigraphic relations was disposed to regard the Farallon bed as possibly Eocene. To harmonize these conflicting indications we may at present regard the bed as intermediate between Eocene and Oligocene; its fauna retaining Eocene foraminiferal forms, mingled with incoming Oligocene molluscan types.

Dr. Bagg's inference that the sample of rock from the Godineau River may be Miocene, calls up the most interesting problem of Antillean stratigraphy, namely whether any true Miocene was ever deposited there. Up to the present no strictly Miocene faunas have been found in the region, although they may yet be discovered.

THE PERNAMBUCO BEDS.

Although many deposits of the coastal plateaus of eastern Brazil from Cape Frio to the Amazon are referred to the Tertiary because of their stratigraphic characters, they are all remarkable for a total absence of organic remains. The only Tertiary beds containing marine fossils have been found in the State of Pernambuco in a narrow coastal belt. The oldest locality is on the Rio Maria Farinha, a small stream emptying into the sea near the town of Olinda.

Dr. Derby was detailed during Professor Hartt's expedition to the Amazon in 1870 to examine this locality. The fossils obtained were described by Dr. Richard Rathbun[4] who referred them to the Cretaceous, without, however, finding any distinctively Cretaceous forms.

In 1875 Professor Hartt himself visited the Maria Farinha beds with Dr. J. C. Branner and others, and obtained a quantity of material for the Geological Commission of Brazil, of which he was then chief.

This collection was neglected for some years because of the sad death of Professor Hartt in Rio. Later the fossils were described, together with many Cretaceous species from other localities, by Dr. White in a monograph[5] published in 1887. He also referred the Maria Farinha fauna to the Cretaceous.

Subsequently the Pernambuco localities were again visited by Dr. Branner who consulted Professor G. D. Harris as to the age of the fossils. The latter said that the fauna was not older than Midway Eocene.

Dr. Branner then adopted this view and remarked that the "general aspect of the faunas of the Pernambuco (Maria Farinha, Olinda, and Ponto das Pedras) and Para basins is decidedly Tertiary rather than Cretaceous."

In 1896, Professor Harris[6] mentioned the close affinity between the Midway of Alabama and that of "the so-called Cretaceous (really Eocene) of Maria Farinha." He added: "No one at all familiar with our Midway fauna can fail to see the close affinities or perhaps identity of *Harpa* (*Pseudoliva*) *dechordata*

[4] Proc. Boston Soc. Nat. Hist., pp. 241–256, 1875.
[5] Arch. do Museu Nac. do Rio de Janeiro, vol. VII.
[6] Bull. Am. Pal., vol. I, p. 40, 1896.

White, *Calyptraphorus chelonitis* White, *Fasciolaria?* (*Mazzalina*) *acutispira* White, *Turritella sylviana* Hartt, *Nautilus* (*Enclimatoceras*) *sowerbyanus* White *non* Orb., *Gryphæa trachyoptera* White, *Cucullæa hartti* Rath. . . . with Gulf State species."

But in Dr. Branner's latest publications on this subject, his faith is shaken in the Tertiary age of the Maria Farinha beds largely because of the reported discovery of a Cretaceous cephalopod on the island of Itamarica which lies off the Pernambuco coast.

Dr. Derby, State Geologist of Brazil, is now also more strongly disposed to regard the Maria Farinha and related faunas of nearby localities as Cretaceous. In his latest article on the subject he writes: "The geological horizon of the beds with faunas of Tertiary aspect is doubtful, but at present the preponderance of evidence seems in favor of a Cretaceous age."

In view of this difference of opinion, and the uncertainty of the age of the Maria Farinha and related Brazilian faunas, the discovery of the Midway beds on Soldado Rock is most illuminating. On that islet, as shown in the preceding pages, we have found typical North American Midway species together with characteristic Maria Farinha forms, and also species common to all three localities—Alabama, Soldado, and Maria Farinha.

By this commingling of species Soldado Rock links the Alabama basal Eocene fauna with that of Maria Farinha, Brazil. Thus the age of the Pernambuco beds (Maria Farinha, Olinda, and Ponto das Pedras formations) is established as Midway Eocene.

AFFINITIES OF SOUTH AMERICAN EXTINCT FAUNAS.

Great stress has been laid on the resemblances of the ancient forms of life of South America to those of contemporaneous times of the Old World. Relationships have been established between the South American faunas and those of France, Spain, Malta, Morocco, Egypt, Syria, India, and South Africa; but until Dr. Derby's work on the Paleozoics of Brazil little was said of the faunal relationships of the two Americas. In fact it was generally supposed that hardly any communication had taken place between the species peopling North and South America.

To account for the similarity of faunas in the eastern and western hemispheres, and to render possible the migrations of species not pelagic, authors have bridged the ancient seas by imaginary continents.

The most famous of these is Atlantis, which furnished a route passing northeastward and eastward from the island of Trinidad to southern Europe and northern Africa. This land is thought by some to have been a continent, by others an island chain. Unfortunately for this hypothesis, about which is woven the charm of Greek and Egyptian tradition, there lie in the present bed of the Atlantic several very deep basins (as the Virgin Islands deep) in the line of the hypothetical land bridge.

A second hypothetical route lay further south and connected the southern part of South America with South Africa. This is thought to have been formed by a northern extension of Antarctica. A strong argument in favor of this is that the present floor of the ocean shows in that region a plateau-like elevation.

As regards the hypothetical eastern lands lying off South America we find ourselves in a dilemma: our knowledge of continental growth indicates that the lands and seas have not changed places to any great extent; yet we are confronted by indirect evidence of the existence of such a land mass,—*first* by the necessity of a pre-existing mass to supply the rock debris for building up the oldest known rocks of northern South America, and *second* by certain faunal relations with the eastern hemisphere.

Messrs. Katzer, Guppy, Jukes-Brown and Harrison, from examinations of the order of deposition of the rock formations of Brazil, Trinidad and Barbados, agree in the conclusion that the material composing the oldest rocks in those areas were furnished by a former land extending to the eastward and northeastward (virtually Atlantis). This is thought to have existed during the Cretaceous and early Tertiary times, then to have been gradually submerged, disappearing beneath the sea in the mid-Tertiary. The crystalline highlands of Guiana and Brazil are looked upon as originally the western end of this vanished continent of which they now constitute the isolated ruins.

But, as above noted, several of the greatest depths of the Atlantic now overlie this supposed sunken continent. It is, however, true that the occurrence of Foraminiferal beds in the southern Antilles, containing genera now found living at great depths, shows that very unusual changes of level have taken place there, and it may be that the normal standards of continental stability cannot be applied in that area.

As regards the South American faunal relations, the discovery of a basal Eocene formation on Soldado Rock containing fossils some of which are common to the southern United States and to Brazil,—joined with Dr. Heilprin's and Dr. Dall's earlier discoveries of the relationship of the Antillean with the Floridian Oligocene—has awakened the writer's belief that the affinities of the Tertiary faunas of South America are far stronger with North America than, as was previously supposed, with the Old World.

From the recent to the early Paleozoic the following faunal resemblances are indicated between the Americas.

But it is true that certain very interesting relationships also exist between the faunas of South America and the Eastern hemisphere. The most striking instances are (1) the well known Devonian *Leptocœlia flabellites* fauna which not only is common to North and South America, but is also found on the Falkland Islands and in South Africa; (2) the famous *Glossopteris* flora of the Carboniferous; and (3) the Cretaceous Ammonitic fauna of which the typically South American genus *Pulchellia* has been traced by Douvillé and others through the Alps as far east as Roumania and even into Asia. These pelagic forms were

presumably carried by oceanic currents corresponding to the present Gulf Stream eastward; but the spread of the other genera cannot thus be accounted for. Possibly we have in these instances cases of parallelisms of development.

Recent and Quaternary.	South America. Molluscan fauna northward from the La Plata.	North America. Molluscan fauna southward from Cape Hatteras.
Oligocene	Upper Oligocene faunas of Cumana, Trinidad, Jamaica.	Upper Oligocene of Florida. (Tampa silex beds, Chipola marls.)
	Lower Oligocene faunas of San Fernando and Manzanilla, Trinidad.	Lower Oligocene of Vicksburg, Mississippi.
Eocene.	Lignitic fauna of Soldado Rock, Gulf of Paria.	Lignitic fauna of Alabama and other Gulf States.
	Midway fauna of Soldado Rock and Pernambuco.	Midway fauna of Alabama and other Gulf States.
Cretaceous.	Cretaceous faunas of Venezuela and Colombia.	Cretaceous of the southwestern United States and Mexico.
Carboniferous.	Faunas of the Amazonian Valley in Brazil, Bolivia and Peru.	Coal measures of the western United States. (More than half the species being identical.)
Devonian.	Ereré formation, Brazil.	Onondaga of the United States.
	Maecuru beds, Brazil.	Oriskany of Alabama, etc.
Silurian.	Brazilian and Venezuelan Silurian faunas (Upper formation).	Niagaran of the United States.
	Brazilian Silurian faunas (Lower formation).	Clinton and Richmond of the United States.

As above noted, the Oligocene faunas of Cumana, Trinidad, and the Antilles in general, show close resemblances to the recent fauna of the west coasts of Central America and of northwestern South America. This is due to the pre-Oligocene free waterway over the Isthmus from the Caribbean to the Pacific.

Regarding the resemblances of the Trinidad and other Antillean Oligocene to that of southern France, the writer's observations of Tertiary forms in general are the same as those of M. Douvillé for the South American Cretaceous,—namely, that although the European and American formations include a very few species in common and have a certain *air de famille*, their evolution was distinct.[7]

Studies by Drs. Dall and Verrill of the living molluscan and coral faunas of Florida and the West Indies indicate that the present faunas on the shores of the Gulf Coast of the United States came originally from the coast of Brazil. And, as Dr. Branner has already suggested, it seems very probable that the Tertiary faunas of the Gulf States may have also originated on the Brazilian and Antillean shores. The Soldado Eocene fauna is a strong argument in favor of this hypothesis.

[7] Ann. de la Soc. Royale Zoologique et Malacologique de Belgique, t. XLI, pp. 142–155, 1906.

DESCRIPTIONS OF SPECIES.

Class PELECYPODA.

Genus OSTREA Linnæus, 1758.

Ostrea crenulimarginata Gabb. Plate V, Figure 11; Plate VI, Figures 1, 2, 3, 4.

Ostrea crenulimarginata Gabb, Jour. Acad. Nat. Sci. Phila., 2d ser., vol. IV, p. 398, pl. 68, figs. 40, 41, 1860.
Ostrea denticulifera Gabb, *Ibid.*, p. 398. Not of Conrad.
Ostrea præ-compressirostra Harris, Ark. Geol. Surv., vol. II, p. 39, 1894.
Ostrea compressirostra Langdon, Geol. Surv. Alabama, p. 413, 1894. Not of Say.
Ostrea tumidula Aldrich, Geol. Surv. Alabama, p. 242, pl. 14, figs, 1, 2, pl. XV, figs. 1, 2, 1894.
Ostrea crenulimarginata Harris, Bull. Am. Pal., vol. I, pp. 159–160, pl. I, figs. 1, 1a, pl. II, figs. 1, 1a, pl. III, fig. 1, 1896.
Ostrea crenulimarginata Dall, Trans. Wagner Inst. Sci., vol. III, p. 677, 1898.

Gabb's original description.—"Subtriangular, sometimes elongated, oval, attached; portion of the outside of the shell not attached is very squamose; hinge about an equilateral triangle, central groove of the hinge deep; internal margin strongly crenate, muscular impression large; upper valve ?

"*Dimensions.*—Length 2.2 in., greatest width about 2 in."

Type locality near Middleton, Tennessee, in Midway Eocene marls.

Remarks.—Gabb was misled by the great dissimilarity in appearance of the convex, plicated left (or lower) valves and the nearly flat, smooth right (or upper) valves of this species; and gave to the former the name *crenulimarginata* and to the latter *denticulifera*, supposing them to be two species.

Among the oysters from Soldado Rock, Bed No. 2, are a number of almost flat valves, of elongated oval, or elliptical outline, and sculptured only by rather coarse concentric lines of growth. These, so far as one can judge from the exterior, agree well in form with the flat valves of specimens of *O. crenulimarginata* from the Midway of Alabama.

A young *Ostrea* shell was found in Bed No. 2, which shows the characteristic crenules on the inner margin. It is much like specimens of a varietal form found near Midway, Alabama,which are flat and nearly circular in outline. This shell shows on the exterior faint radial striæ.

We have also from Bed No. 6, Soldado Rock, a single convex valve embedded in a silicious matrix with a mass of Foraminifera. The hinge area and a portion of the exterior is, however, revealed. The former shows along the margin fine striations, like specimens of *crenulimarginata* but somewhat closer and finer; and the surface of the shell shows traces of the rather regular, narrow plications characteristic of the left valves of this species. As the general outline also agrees, the writer is inclined to think that the shell from Bed No. 6 is a left valve of *O. crenulimarginata*.

Locality.—Beds Nos. 2 and 6, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene (Bed No. 2) and near the Midway and Lignitic contact zone (Bed No. 6).

Ostrea cynthiæ new species. Plate VI, Figure 5.

Description.—Shell large, heavy, becoming greatly thickened, general form obliquely ovate-oblong; left (lower) valve very convex, not plicated, marked by thick, irregular concentric lamellæ marking resting periods of growth; right (upper) valve flat, operculate in form, not sculptured; hinge not heavy, considering the weight of the shell.

Height 140, greatest breadth 90 mm.

Remarks.—These oyster shells have been almost wholly replaced by silica, only a few narrow layers of the original calcite remaining deep in the inner portion of the shell. The silicious deposits form on the surface very curious concentric structures, one of which is shown in the figure near the base of the valve.

This oyster is unlike any described from the lower Eocene of either North America or Brazil.

It is with great pleasure that the writer names the species in honor of Mrs. Arthur Sewall, of Philadelphia.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Ostrea golfotristensis new species. Plate VII, Figure 1.

Description.—Valves rather thin, when complete, ovate-oblong in form; sculpture of very many fine, close-set, radiating riblets, divaricating, fairly regular; hinge with a narrow, rather deep ligament pit.

Height of fragment 15 mm.

Remarks.—Superficially this curious shell resembles somewhat a Midway Alabama fossil mentioned by Professor Harris as *Plicatula* species,[8] but the Soldado shell has no teeth,—only the deep ligament pit showing it to be an *Ostrea*.

It appears to be of the group of Lea's *Ostrea divaricata*;[9] but the divaricating riblets are very much finer and more close-set than in that species. The form of the shell is also much less oblique.

The specimens are all more or less broken. The curious aspect of this shell is enhanced by the fact that it is colored moss-green, magenta, and violet by presumably some marine algal growth that has encrusted it. The peculiar formation of concentric rings of silicon on the surface has begun in some cases. This is noted at greater length in the description of the other Ostreas from Soldado.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Ostrea cf. percrassa Conrad and compressirostra Say. Plate VI, Figure 7.

Among the Ostreas from Bed No. 2, Soldado Rock, is a very bizarre specimen. It was evidently originally a large rounded oyster of the general shape of *O.*

[8] Bull. Am. Pal., vol. I, p. 161, pl. 2, figs. 2, 2a, 1896.

[9] Contributions to Geology, p. 91, pl. 3, fig. 70, 1833.

percrassa or *O. compressirostra;* but it has become completely hidden by a most singular deposit of silicon in concentric rings. Apparently, the two valves rest together with a layer of the silicious rock matrix between. The surface of the convex valve has been completely encrusted by the concentric rings of silicon, so as to be perfectly hemispherical; while the flat valve is completely hidden in four layers of similar but finer concentric rings of the same character. The singular appearance of this most curious specimen is heightened by the brilliant coloring of the silicious circles which vary from deep violet, moss green, and white to vivid pink.

This coloration is shown to be due to some organisms probably marine algæ that were living on the surface of the rings. For when heated in the flame of a bunsen burner the pink color turns black and then fades out, a sure proof that it is organic.

It is needless to say that identification of the oyster shell forming the nucleus of this mineral growth is impossible. But attention is called to the structure, as it is so very unique and characteristic. The beginnings of the formation of the concentric rings have been seen on other fossils in this bed, as on *Ostrea cynthiæ*, but in this case it has been carried to an extreme development.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene.

Ostrea pulaskensis Harris. Plate VII, Figure 2.

Gryphæa vomer Safford, Geol. of Tennessee, p. 419, 1869.
Gryphæa pitcheri Morton? White, Proc. U. S. Nat. Mus., vol. IV, p. 137, 1881.
Ostrea pulaskensis Harris, Ark. Geol. Surv., vol. II, p. 40, pl. i, figs. 3, a–d, 1892.
Gryphæa vomer Langdon, Geol. Surv. Alabama, p. 416, 1894.
Ostrea pulaskensis Harris, Bull. Am. Pal., vol. I, pp. 160–161, pl. i, figs. 2, a–c, 3, a, 1896.
Ostrea pulaskensis Dall, Trans. Wagner Inst. Sci., vol. III, p. 677, 1898.

Harris' original description.—"Outline of the larger valve right angle-triangular; a carination from the umbo to the posterior basal margin forming the hypothenuse, the basal margin the base, and the shorter margin from umbo to base the perpendicular with proportional lengths of 8, 7 and 5 respectively; beak generally very incurving; carination often very pronounced; between it and the margin of the valve are one or two more or less distinct sulci; surface comparatively smooth, though possessing a few slight concentric undulations, which, curving upwards in the middle of the valve, form a very shallow sulcus extending from beak to base; muscular impression not distinctly marked; lesser valve thin, flat, circular; marked exteriorly by lines of growth, smooth within, with an oval muscular impression which is submarginally located.

"This description, and the figures referred to, show the most Gryphæa-like phase of this species. Other forms are less distinctly sulcate and carinate."

Midway Eocene of Texas, Arkansas, Tennessee, Mississippi, Alabama, and Georgia.

Remarks.—A specimen of this curious little oyster from Soldado Rock can

be almost perfectly duplicated by shells of the same species collected by Professor Harris from the basal Eocene of Alexander, Arkansas.[10] There can be no question of their identity. The Soldado convex valve measures in height 22, greatest width 18, greatest thickness 14 mm.

This species is closely allied to *O. thirsæ* Gabb, which is the Lignitic analogue of this Midway shell.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to that of Alabama and of the Rio Maria Farinha beds, Brazil.

Ostrea thalassoklusta new species. Plate VI, Figure 6.

Description.—Shell small, subcircular in outline, large valve moderately convex; hinge margin slightly alate; basal margin sinuous; valve smooth except for a deep, rather broad sulcus which extends from the umbonal region to the basal margin of the shell, rendering the central part of the valve concave.

Height of larger valve 23, greatest width 21, greatest thickness 10 mm.

Remarks.—This *Ostrea* is closely allied to both the Midwayan *O. pulaskensis* Harris and to the Lignitic *O. thirsæ* but it can readily be distinguished from both by its subcircular form, and especially by the characteristic, deep sulcus which takes the place of the umbonal-basal ridge in those species. Where they are convex it is concave.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene.

Ostrea thirsæ Gabb. Plate V, Figures 6, 7, 8.

Ostrea emarginata Tuomey (name only), 2d Biennial Rept. Geol. Surv. Alabama, p. 269, 1858.
Gryphæa thirsæ Gabb, Proc. Acad. Nat. Sci. Phila., p. 329, 1861.
Ostrea thirsæ Heilprin, 3d Ann. Rept., U. S. Geol. Surv., p. 311, pl. 63, figs. 4–6, 1884.
Gryphæa thirsæ Aldrich, Bull. I, Geol. Surv. Alabama, p. 58, 1886.
Ostrea thirsæ Harris, Bull. Am. Pal., vol. I, pp. 232–233, pl. 6, figs. 5, 6, 1896.
Ostrea thirsæ Dall, Trans. Wagner Inst. Sci., vol. III, p. 680, 1898.

Gabb's original description.—"Rounded, sub-triangular. Lower valve; beak very small, and close to the hinge, never exsert. Umbone rounded, very prominent and somewhat compressed laterally, the rounded elevation continuing more or less regularly, becoming broader to the middle of the basal margin, at which point this margin is always somewhat emarginate. Ligament area broad, triangular, transversely striate, and with a slight irregular depression in the middle. Interior of valve very deep. Muscular impression nearly ovoid, narrowest on the inner side. External surface marked by a few small, irregular, squamose ridges, most numerous and distinct directly behind the emargination of the base. Upper valve unknown.

"The species resembles, remotely, some of the narrower forms of *G. vesicularis* Lam., but after comparing the series before me with numerous authentic specimens of that species, both American and European, some of the latter labelled

[10] Cornell Paleontological Museum, No. 8400.

by d'Orbigny and others by Charlesworth, I am satisfied that they are distinct. The beak is so small as to be almost obsolete, and there is always a more or less distinct, rounded, umbonal ridge. In general form, it resembles *G.* (*Exogyra*) *columba*, but wants the spiral beak, and is never lobed. The small beaks and absence of all traces of lobes will sufficiently separate it from *G. pitcherii*.

"Length 1.7 in. Greatest width 1.3 in."

Type locality, Nanafalia, Alabama, in the Lignitic Eocene.

Remarks.—This is a very common shell in the fauna of Bed No. 6, Soldado Rock. Specimens from that locality match exactly in size and shape others from Nanafalia, Alabama. The species has been found only in the Lignitic.

Geological horizon.—Lignitic Eocene.

Ostrea abrupta d'Orb. variety ? Plate V, Figures 1, 2.

Cf. *Ostrea abrupta* d'Orbigny, Voyage dans l'Amérique Mérid., T. 3, 4e partie (Paléontologie), p. 93, pl. 21, figs. 4–6. Republished by Coquand, Monog. du Genre Ostrea, Terrain Crétacé, p. 175, pl. 63, figs. 1–3.

Mr. Veatch found in Cretaceous beds on the route to El Pilar, near Coycuar, Venezuela, a slab with plicated oysters which Dr. Stanton refers to the group of *Ostrea abrupta*, described by d'Orbigny from the Cretaceous of Colombia. Dr. Stanton adds, however, that the Venezuelan specimens are much smaller than the type and lack some other characteristics. So that in order to identify them with d'Orbigny's species it would be necessary to assume that the specimens are immature and that the species varies even more than the original description indicates.

Geological horizon.—Cretaceous.

Ostrea puelchana d'Orb. Plate V, Figures 3–5, 9, 10.

On the Union Estate, Brighton, Trinidad, Mr. Veatch found two horizons characterized by oyster shells. These at first seemed to be distinct species, but the difference is chiefly one of size. They are referred by Dr. Dall to *O. puelchana*, which Dr. Dall suggests might be shown to be a southern form of *virginica* if a complete series could be obtained.

It is interesting to note also that Dr. Guppy has referred the specimens of *O. haitensis* Sby. found on Trinidad to *virginica*. The probabilities are that this was the very species that Dr. Guppy had in mind. For certainly the Union Estate shells are remarkably close to a varietal form of *virginica* now living in the Gulf of Mexico.

Localities.—The large form was found in a bed 1000 feet north of the Forest Reserve Road. This bed is stratigraphically about 4000 feet above the Soldado bed.

The small form characterized a layer half a mile from Bamboo Junction. Stratigraphically this bed lies 210 feet below the large oyster horizon.

Geological horizon.—Upper Oligocene.

Genus **PLICATULA** Lamarck, 1801.

Plicatula torta Gabb? Plate VII, Figure 3.

Cf. *Plicatula torta* Gabb, Cretaceous of Peru, Jour. Acad. Nat. Sci. Phila., vol. VIII, p. 295, pl. 42, fig. 5, 1877.

Mr. Artie Reeds collected a single specimen of an interesting shell which is doubtfully referred by Dr. Stanton to *Plicatula torta*, described by Dr. Gabb from the Cretaceous of Peru. The shell is unfortunately too fragmentary for any positive identification.

Height of the shell 27 mm.

Locality.—Headwaters of the Rio Grande, one mile north of where the river crosses the trail to Guariqueen, Eastern Venezuela.

Geological horizon.—Cretaceous.

Genus **SPONDYLUS** Linnæus, 1758.

Spondylus sp. indet. Plate VII, Figure 4.

Among the shells from Soldado is a fragment of a *Spondylus* too imperfect and fragmentary to describe.

On comparing it with the specimens of *S. bostrychites* Guppy var. *chipolanus* Dall, from the Oligocene of Florida, which it resembles somewhat in type of sculpture, it is found to differ in having the fine radiating ribs always paired or furrowed down the center so as to appear double.

The genus *Spondylus* is rare in both the Tertiary and recent faunas. This is the first ever found in the Midway or Lignitic.

Locality.—Bed No. 8, Soldado Rock.

Geological horizon.—Lignitic Eocene.

Genus **PERNA** Bruguière, 1792.

Perna obliqua Lamarck. Plate VII, Figure 6.

The characteristic manner in which these shells burrow in the rocks of the Gulf of Paria is shown by the illustration.

Locality.—Black Rock, near Soldado, Gulf of Paria.

Geological horizon.—Recent.

Genus **INOCERAMUS** J. Sowerby, 1819.

Inoceramus labiatus Schlotheim. Plate VII, Figures 7, 8.

Inoceramus labiatus Schlotheim, Bronn's Jahrb., vol. VII, p. 93, 1813.
Inoceramus mytiloides Mantell, Geol. of Sussex, p. 215, pl 28, fig. 2, 1822.
Inoceramus aviculoides Meek and Hayden, Proc. Acad. Nat. Sci., Phila., p. 181, 1860.
Inoceramus plicatus (d'Orbigny) Karsten, Géologie de l'ancienne Colombie Bolivarienne, Vénézuela, Nouvelle-Grenada et Ecuador, p. 18, 1886.
Inoceramus labiatus Stanton, Bull. U. S. Geol. Surv. No. 106, pp. 77–78, pl. X, fig. 4, pl. XIV, fig. 2, 1893.

Meek's description.—"Shell obliquely elongate-oval, subelliptical or ovate, nearly or quite equivalve, rather compressed, thin and fragile; anterior side forming a slightly convex curve from the beaks obliquely downward and back-

ward, postero-basal extremity rather narrowly rounded; postero-dorsal margin very oblique, compressed, nearly straight, or sometimes a little convex in outline below the middle, and slightly concave above, cardinal border short, straight, compressed, and forming an angle of about 45 degrees with the longest diameter of the shell; beaks terminal, rather small, nearly equal, obtusely pointed, rising little above the hinge, and not much incurved. Surface ornamented by more or less regular, concentric undulations, and smaller marks of growth."

Remarks.—While in Venezuela the writer sent a box of *Inoceramus* specimens to Dr. Stanton, of the United States Geological Survey, that had been obtained by Mr. Veatch and the writer from ravines along the trail from Guanoco to the little temiche hut village of Hurupu. Dr. Stanton very kindly examined the material and wrote as follows:

"The collection from near Guanoco, on the trail to Hurupu, includes a number of specimens of an *Inoceramus* which is almost certainly the species identified by Karsten as *Inoceramus plicatus* d'Orbigny which he reported from the valley of Cumanacoa, eastern Venezuela, and from many other localities in that country. He states that the species occurs at Barbacoas, Province of Trujillo, associated with several species of Lower Cretaceous ammonites and on the basis of this identification and association he refers the *Inoceramus*-bearing rocks of eastern Venezuela to the Lower Cretaceous. *Inoceramus plicatus* was originally described from supposed Lower Cretaceous rocks near Ibaque, Colombia. The fact should be noted, however, that this species is very closely related to *I. labiatus* of the Upper Cretaceous and the specimens in your collection can be almost exactly duplicated by specimens of *I. labiatus* from the Benton of the Rocky Mountain region."

Later more material was obtained from the same locality and among the specimens was one in shale (see figure) which resembles greatly the figures of *I. labiatus* in Dr. Stanton's report on the Colorado Formation.[11] This and Dr. Stanton's comparisons incline the writer to regard the Venezuelan shell as a form of this widely distributed species.

Inoceramus labiatus is common in the Niobrara limestone of Kansas, Nebraska, Colorado, and the Upper Missouri region. It is also abundant in the Fort Benton shales in the same states and in equivalent strata in Utah. New Mexico, Texas, and northern Mexico. In Europe it is said to be found only in the Lower Turonian and in southern India it is limited to the Ootatoor group which forms the base of the Upper Cretaceous section of that region.

This species is exceedingly common in certain layers of the Cretaceous limestones in the vicinity of Guanoco. It occurs generally in very dark, exceedingly hard, cherty limestone beds; but it is also found in the Cretaceous shales associated with them. The shells vary from a characteristically deeply and evenly grooved concentric sculpture to nearly smooth forms with the sculpture almost obsolete. This causes them at first glance to appear as different species, but

[11] Bull. U. S. Geol. Surv., No. 106, pl. XIV, fig. 2.

further study convinces one that they are mutations of one species. All sizes occur, but a rather large shell measures about 55 mm. in length and 45 in breadth.

As indicated in the synonymy given above, Karsten's *plicatus* is referred, tentatively at least, to *labiatus*.

Locality.—Ravines on the right and left sides of the trail from Guanoco to Hurupu, on the hillside just above the stream called Rio Colorado. Longitude approximately 3° 59′ 6″ east of Caracas; latitude approximately 10° 8′ north of the equator.

Geological horizon.—Probably Upper Cretaceous, about equivalent to the Turonian horizon of Europe and the Benton of the United States. Possibly as old as the Gault, but according to Dr. Stanton, not older than that period.

Genus **MODIOLA** Lamarck, 1801.

Modiola cf. alabamensis Aldrich. Plate VII, Figure 9.

Cf. *Modiola alabamensis* Aldrich, Bull. Am. Pal., vol. I, p. 68, pl. 5, fig. 13, 1895; Harris, *Ibid.*, vol. II, p. 239, pl. 7, fig. 9, 1897.

Remarks.—A single fragment of a *Modiola* shell was found at Soldado. Unfortunately it is too incomplete for any positive identification or description; but the radiating striæ ornamenting the surface almost exactly match those on a specimen of *alabamensis* from the Lignitic Eocene of Woods Bluff, Alabama, in the Paleontological Museum of Cornell University. It is quite possibly identical with Mr. Aldrich's species.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Genus **ARCA** Linnæus, 1758.

Arca (Noetia) sheldoniana new species. Plate VIII, Figures 10, 11.

Description.—Shell small, rather delicate for the genus, nearly rhomboidal, high and short; posterior slope carinate, very slightly produced; beaks nearly touching, opposite the middle of the row of teeth; moderately inflated; interstitial rib present on the posterior half of the valve.

Length 15; height 13.5; thickness of one valve 6 mm.

Remarks.—This shell has somewhat the outline of *Arca* (*Noetia*) *ponderosa* Say[12] of the Pleistocene and recent faunas of the Atlantic and Gulf coasts. But an examination of the ligamental area shows that it is not *ponderosa* because the ligament is wholly anterior and ends at the beak, as in the recent west coast species, *A. reversa* Gray. It is, however, not *reversa* because it has not so sharp a posterior slope as that species which is, moreover, now limited to the Pacific coast.

Thus we have a shell with the outline of the east coast *ponderosa* and the cardinal area characteristic of the west coast *reversa*. The fossil shell is intermediate between these two species and is an interesting indication of the diver-

[12] Jour. Acad. Nat. Sci. Phila., 1st series, II, p. 267, 1822.

gence of the west coast species from a common stock in the Antilles from which it migrated westward before the rise of the isthmus.

The short, high type of Noetias of which *A. sheldoniana* is an example is found in the Oligocene beds of the east coast but apparently at the close of that period it died out in the Antilles. On the west coast it continued to develop to the present time where the type is represented by *Arca* (*Noetia*) *reversa*.

Arca trinitaria[13] described by Dr. Guppy from the Manzanilla beds of Trinidad (which Dall and Guppy in 1896 called probably Eocene but which Dr. Dall later thought to be Oligocene) is of the same short high type of *Noetia*. It also died out. Although evidently a near relative of that species *A. sheldoniana* is not nearly so produced posteriorly and is specifically distinct.

Locality.—Along the shore 1000 feet west of Brighton Pier, Trinidad Island, in a black asphaltic marl.

Geological horizon.—Approximately equivalent to the Chipola (Upper Oligocene) epoch of Florida.

This shell is dedicated to Miss Pearl Sheldon, of the Geological Department of Cornell University, who has just completed a monograph on the genus *Arca* and to whom the writer is indebted for help in the differentiation of this species.

Arca (Cunearca) chemnitzioides new species. Plate VII, Figures 13, 14, 15; Plate VIII, Figure 1.

Description.—Shell trigonal, short and high with prominent and widely separated beaks; cardinal area diamond-shaped with transverse striations and without V-shaped grooves; this and the general form show it belongs to the section *Cunearca*. Nearly all the specimens are in the form of internal moulds, but several were casts of the exterior and gutta-percha impressions of these show the ribs were beaded as indicated in the figure.

Length of an averaged sized mould 22; height 21; diameter 16.5 mm.

Remarks.—Judging from these characters the shell might be taken to be *Arca* (*Cunearca*) *cumanensis* Dall[14] from the Oligocene of Cumana, Venezuela, and from an island in Lake Henriquillo, St. Domingo. This species has never been figured but it is so like *Arca incongrua* Say[15] that Dr. Guppy referred it to that species in his list of the Tertiary shells of the West Indies[16] and Dr. Dall in describing *cumanensis* says it resembles *incongrua* closely, although the valve is shorter and higher. The high narrow beaks and wide cardinal area separate the Trinidad fossil from *incongrua*. And its general aspect is so unlike that species that it could hardly be *cumanensis* which Dr. Dall says is like *incongrua* in miniature.

But the Trinidad shell recalls at once *Arca chemnitzii* Philippi of the recent east coast fauna, and also an ancestral form of that species *Arca alcima* Dall[17] from the Pliocene of Florida. A gutta-percha mould of a specimen of *A. chemnitzii*

[13] Proc. Geol. Soc. London, vol. 22, p. 583, pl. XXVI, fig. 3a, 3b, 1866.
[14] Trans. Wagner Inst. Sci., III, pp. 633–634.
[15] Jour. Acad. Nat. Sci. Phila., II, p. 268, 1822.
[16] Geol. Mag., 1874, p. 451.
[17] Trans. Wagner Inst. Sci., III, pp. 635–636.

collected by Mr. Schultz in a sandy cave south of Brighton on the Gulf of Paria is almost exactly the shape of the moulds of the fossil shells. But some of the latter appear to have been of considerably larger size than the recent forms attains.

Locality.—Southern main road just south of Pitch Lake, Brighton, Trinidad Island, in a reddish-yellow, highly ferruginous marl. Lithologically the formation is very like that of the Lignitic Eocene at Many, Louisiana.

Geological horizon.—Arcas of this type characterized by high umbones and short high form of shell are not known below the Oligocene on the southeastern coast of the southern United States and the Antillean area. Hence short, high Arcas mean Oligocene or later. Such types have been found in beds called Eocene but which proved later to be really Oligocene. An instance of this is *Arca filicata* Guppy, a form related to the species described above, from the Manzanilla beds of Trinidad. These were first thought to be Lower Miocene[18] then Eocene,[19] then Oligocene.[20] From these indications the bed with ferruginous casts would appear to be Oligocene or later.

Arca (Argina) billingsiana new species. **Plate VIII, Figures 2, 3.**

Description.—Shell transversely oval-elongate, rather thick and strong, beaks nearly touching, incurved over the narrow cardinal area which is similar to that of *Arca campechensis* Dillwyn, ribs of the left valve generally simple, sometimes faintly grooved, about 29 in number.

Length of shell 31; height 22, thickness of one valve 10 mm.

Remarks.—This species recalls the outlines of members of *Scapharca* (*Scapharca*) *transversa* Say[21] group; but the hinge shows the characters of Gray's section *Argina* (1840) of the subgenus *Scapharca*. In *Argina* the hinge teeth are in two series,—the anterior shorter, more or less irregular and broken, and the posterior longer, normal.

The only members of *Argina* described from the Tertiaries of the Gulf or the Antilles are (1) *Scapharca* (*Argina*) *tolepia* Dall[22] from the Oligocene of Rio Amina, Santo Domingo; Bowden, Jamaica; and Cumana, Venezuela, and (2) *Scapharca* (*Argina*) *campechensis* Dillwyn[23] from both of which the Trinidad shell is specifically distinct.

The Cumana shell, *A. topelia* was referred by Dr. Guppy in his list of the West Indian Tertiary shells[24] to *Arca pexata* Say; but it can be distinguished by its remarkable inflation, its diameter being practically equal to its length.

A recent species of *Argina* was collected by Mr. Alfred Schultz in a sandy cove

[18] Guppy, 1866.
[19] Guppy 1874, Guppy and Dall 1896, Dall 1898.
[20] Dall and others.
[21] Jour. Acad. Nat. Sci. Phila., 1st ser., II, p. 169, 1822.
[22] Trans. Wagner Inst. Sci., III, pp. 649–650, pl. 33, figs. 7, 8, 1898.
[23] Descr. Cat. Rec. Shells, I, p. 238, 1817.
[24] Geol. Mag., London, 1874.

of the Gulf of Paria south of Brighton, almost within a stone's throw of the black, asphaltic outcrop in which the fossil *Argina* was found by Mr. Veatch. This is a closely related form and doubtless the descendant of the fossil species. As the recent form has apparently never been described, it seems well to differentiate it and it is now described and figured as *Arca* (*Argina*) *schultzana*.

Locality.—*Arca billingsiana* was found along the shore, 700 feet east of the Brighton pier, Trinidad Island, in a black asphaltic marl.

Geological horizon.—Approximately equivalent to the Chipola (Upper Oligocene) epoch of Florida.

The shell is named in honor of Dr. John S. Billings, Director of the Libraries of New York City.

Arca (Argina) schultzana new species. Plate VII, Figures 10, 11, 12.

Description.—This recent species has much the aspect of the Oligocene *Arca* (*Argina*) *billingsiana* of which it is undoubtedly the descendant. As with the fossil shell, the outline resembles that of the larger members of the group of *Arca* (*Scapharca*) *transversa* Say, but the species is at once differentiated from those shells by the characters of the hinge teeth. The latter are those of typical *Argina;* a short, broken anterior set and a long, normal posterior row. The ribs number about thirty, cardinal area very narrow, beaks approximate, depressed, placed within the anterior fifth of the greatest length of the shell.

Length 35, height 25, diameter 22 mm.

The shell is named in honor of Dr. Alfred Schultz, of Washington, D. C., by whom it was found.

Locality.—In a sandy cove of the Gulf of Paria, a short distance south of the pier at Brighton, Trinidad.

General horizon.—Recent.

Arca (Argina) brightonensis new species. Plate VIII, Figures 4, 5, 6.

Description.—Shell rather small for the genus, oval-elongate, cardinal area very narrow; hinge teeth in the two unequal series characteristic of the section *Argina*, the anterior set being very short; ribs on the left valve about thirty, lightly grooved over the central portion of the valve.

Length 24, height 17, diameter 16 mm.

Remarks.—At first sight this species was taken for a mutation of *Arca campechensis* Dillwyn[25] of the Pleistocene of the Atlantic and Gulf coasts, and now living on the shores from Cape Cod to the Antilles. But on comparing the Trinidad shell with several hundred specimens of all sizes of *Arca campechensis* from the Gulf of Mexico, I find that the shells of this species of the same size as the Trinidad *Arca* are invariably rounder and flatter. As Dr. Dall[26] has shown, *A. campechensis* is a very protean species, but the typical form is rounder, and

[25] Descr. Cat. Rec. Shells, I, p. 238, 1817.

[26] Trans. Wagner Inst. Sci., III, pp. 650–652.

occurs throughout the southern range of the shell. There are among a number of recent shells collected by Mr. Veatch along the shore of the Gulf of Paria between La Brea and San Fernando, Trinidad, a couple of Arcas of the section *Argina*, which are elongated and of very nearly the same form as the fossil shell of which they are evidently direct descendants. But the beak of the fossil is much higher and the angle of the posterior slope is different. The ribs of the recent shell are about the same in number as in the fossil form and they are also slightly grooved in the left valve. The length of the recent shell is also 24 mm., but the height is 19 and the diameter 14 mm. Hence the fossil was proportionally less high and more inflated.

Both the fossil and the recent Brighton Arginas, though very unlike the typical southern *campechensis*, do somewhat resemble small specimens of the variety *Arca americana* Gray from the Pleistocene and recent fauna of the Carolinas. But that is a much larger shell, and its distribution is much more northern.

This and the great difference of geological horizon seem to warrant our considering the Brighton fossils as a separate species. For its recent analogue, if its slight difference of form and its presence in the recent fauna differentiate it sufficiently from the Oligocene shell, the writer would suggest the name *pariaensis*.

Locality.—Along the shore 700 feet east of Brighton pier, Trinidad Island, in an impure asphalt.

Geological horizon.—Approximately equivalent to the Chipola (Upper Oligocene) epoch of Florida.

Arca (Argina) pariaensis new species. Plate VIII, Figures 7, 8, 9.

This is the recent analogue of the Oligocene *Arca brightonensis*.

For the description of this shell see remarks under that species.

Locality.—Shores of the Gulf of Paria between La Brea and San Fernando where it was collected by Mr. A. C. Veatch.

Geological horizon.—Recent.

Arca sp. indet. Plate VII, Figure 16.

Remarks.—In addition to *Arca chemnitzioides*, which is the most abundant species in the ferruginous bed south of Pitch Lake, there is also a fragment of a cast of a compressed, elongated species. A gutta-percha mould was made of this, which is shown in the figure.

This species was apparently of somewhat the general form of Dr. Guppy's *A. inæquilateralis* but not identical with it. The single specimen is unfortunately too fragmentary to merit description.

Locality.—Southern main road just south of Pitch Lake, Brighton, Trinidad, in a yellowish-brown ferruginous stratum.

Geological horizon.—Oligocene.

Arca sp. indet.

A fragment of an internal mould of an *Arca* was found in the ferruginous marl just south of Pitch Lake, Brighton, that appears to be a different species from

those mentioned, but it is too incomplete for description. The hinge teeth are, however, perfectly preserved and show that the shell was unquestionably an *Arca*.

Geological horizon.—Oligocene.

Genus **CUCULLÆA** Lamarck, 1801.

Cucullæa harttii Rathbun. Plate VIII, Figure 12.

Arca (*Cucullæa?*) *Harttii* Rathbun, Proc. Boston Soc. Nat. Hist., vol. XVII, pp. 248–249, 1875.
Cucullæa (*Idonearca*) *harttii* White, C. A. Archivos do Museu Nacional do Rio de Janeiro, vol. VII, p. 65, pl. V, figs. 7, 8, 1887.
Cucullæa harttii Harris, Bull. Amer. Paleont., vol. I, p. 154, 1896.
Cucullæa harttii Branner, Bull. Mus. Comp. Zoology, Harvard College, vol. XLIV, p. 13, 1904.

Rathbun's original description.—"Shell of medium size, elongate, gibbous, with the height nearly two-thirds the length. Outline of internal mould sub-ovate, the height of the posterior extremity being much greater than that of the anterior. The beaks are situated at a little more than one-third the length from the anterior margin, are very prominent and incline strongly forward. Hinge nearly as long as the shell. The posterior margin extends obliquely downward and slightly backward, rounding strongly toward the ventral margin. The anterior margin leaves the hinge abruptly, at nearly a right angle, and curves rapidly round to the ventral margin, which is slightly rounded and descends moderately in extending backward. The valves are very convex and arch strongly from the beak to the ventral margin. The depth of each valve is more than one-third the height of the shell. The posterior slope commences abruptly, along a line extending from just behind the beaks to the lower posterior corner and descends rapidly to the hinge and posterior margin. This slope is broad, quite concave just back of the beaks, but becomes nearly straight posteriorly. The surface is marked by small, rounded or subangular radiating raised lines, which are very fine at the beaks, where they are of about the same width as the interspaces, or narrower, and increase very gradually in size toward the margin, the interspaces there being much the narrower and even reduced to mere striæ. Fine concentric lines cross the shell; on the upper portion of the shell they are very regular, but near the ventral margin they become more numerous and are crowded together. As they cross the radiating lines they become very prominent, sometimes giving to the latter a beaded appearance. On the posterior slope the radiating lines are minute, threadlike and near together, being separated by very narrow depressions. These seem to be made even more beaded in appearance by the concentric lines than are the radiating lines on the main portion of the shell, though they are exceedingly fine. The inner margin of the shell is crenulated.

"The shell is quite a thick one, and none of the exterior characters appear in the interior, so that the angular appearance presented by the external moulds is not apparent in the very numerous interior ones. The characters of the interior are quite obscure in all the specimens obtained rendering the determination of

the genus a little doubtful. The posterior end of the hinge seems to be marked with the longitudinal teeth peculiar to *Cucullæa*, while in the interior moulds there is a slight, rounded depression bordering the posterior muscular imprint below, and extending some distance toward the beak. As to shape the form is truly Cucullean. Size of a medium specimen: length 27 mm.; height 18 mm.; depth of both valves 16 mm.

"Very abundant, as interior moulds, in the whitish limestone of the Cretaceous at Maria Farinha, Province of Pernambuco, Brazil. Dedicated to my teacher and friend, Prof. Ch. Fred. Hartt."

Remarks.—Cucullæa harttii is by far the commonest shell of the Soldado Rock, Bed No. 2, fauna. Together with *Calyptraphorus*, *Venericardia*, *Turritella* and other less common forms, it makes up a very indurated shell breccia. All sizes of the species occur from very small, young shells, up to the large adult forms like the one figured, which measured 29 mm. in length, 19 in height and 20 in diameter.

This species has never before been found except at the type locality, near the mouth of the Rio Maria Farinha in the State of Pernambuco, Brazil. The type shells were collected in 1870 by Messrs. O. A. Derby and D. B. Wilmot under the direction of Professor Hartt, and were submitted to Dr. Rathbun for study. As Dr. Rathbun did not figure the species and Dr. White's figures were of imperfect specimens, it has been thought best to figure one of the very fine shells from Soldado.

Locality.—Bed. No. 2, Soldado Rock, Gulf of Paria, near the S.W. point of Trinidad.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of Rio Maria Farinha, State of Pernambuco, Brazil.

Genus **GLYCYMERIS** Da Costa.

Glycymeris (Axinea) viamediæ new species. Plate VIII, Figure 13.

Description.—Shell small, ovate-orbicular, thin, slightly convex; beaks low, inconspicuous, pointed, approximate; teeth concealed in all the specimens by the silicious matrix; concentric sculpture of several lightly impressed crenulate lines of growth, irregularly disposed, marking resting stages; radial sculpture of very delicate, narrow, flattened riblets alternating with microscopic, radial threads.

Height of shell 16, length 17, diameter 8 mm.

Remarks.—This very pretty and delicate shell is the first of the genus ever found in the Midway or earliest Eocene.

It was rather a common shell in the Soldado fauna, as we have a number of specimens. The one figured, although showing the sculpture best, has a more sloping hinge line than the majority of the shells.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to that of the Midway of Alabama and of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Mo. Bot. Garden
1913

Genus **UNIO** Philipsson, 1788.

Unio sp. indet. Plate VIII, Figures 18, 19.

A number of casts of large molluscan shells were collected by Mr. Veatch along the shores of the Gulf of Paria, in a white, decayed limestone rock. None can be specifically determined, and the majority not even generically. The example referred to above, however, fortunately shows the characteristic heavy, alternating teeth of *Unio*.

Locality.—One mile west of the Godineau River, about midway between San Fernando and La Brea, along the shores of the Gulf of Paria, Trinidad.

Geological horizon.—Probably Oligocene, from its stratigraphic position, but no evidence can be gathered from the fossil because of its very imperfect condition.

Unio sp. indet. Plate IX, Figure 1.

It is not possible to say positively whether these shells are remains of a large *Mactra* and hence of marine origin, or fragments of a large *Unio* and of freshwater origin. Their state of preservation is exceedingly imperfect. But the association of one with the cast of a smaller shell showing the teeth of *Unio* inclines one to believe them members of the latter genus.

Locality.—One mile west of the Godineau River, along the shore of the Gulf of Paria, about midway between La Brea and San Fernando, Trinidad, in a white, decayed limestone rock.

Geological horizon.—Probably Oligocene, judging from the stratigraphic position of the bed.

Genus **ANODONTA** Lamarck, 1799.

Anodonta ? sp. indet.

Remarks.—Associated with the moulds of a large and small species of *Unio* in the white, decayed lime rock between La Brea and San Fernando, is the mould of a large, convex shell which has much the aspect of an *Anodonta*. Its form recalls such species as *A. grandis* of North American rivers and the larger, similarly shaped *A. gigantea* Spix from the rivers of Brazil.

Locality.—One mile west of the Godineau River, along the shores of the Gulf of Paria, about midway between La Brea and San Fernando, Trinidad.

Genus **VENERICARDIA** Lamarck, 1801.

Venericardia alticostata Conrad.

Cardita alticostata Conrad, Amer. Jour. Sci., vol. XXIII, p. 342, 1833.
Venericardia perantiqua Conrad, Amer. Jour. Conch., vol. 1, p. 8.
Venericardia alticostata Harris, Bull. Am. Pal., vol. I, pp. 171–172, pl. 4, fig. 12, 1896.

Conrad's original description.—"Shell subcordate, convex, with about twenty-two profoundly elevated nodulous ribs, which on the anterior side are laterally carinated. Length two inches."

Type locality, Claiborne, Alabama.

Remarks.—Several specimens of this species are in the indurated shell breccia

from Soldado Rock, which match exactly small specimens of *V. alticostata* in the Paleontological Museum of Cornell University from the Lignitic Eocene of Woods Bluff, Alabama. They answer perfectly to Conrad's description and show the characteristic carinating line on the anterior side of the ribs.

This species has also been found in the Midway of Texas and Alabama by Professor Harris. At the very base of the Midway beds at Snow Hill, Alabama, he has found a very small ancestral form, about one centimeter in length. Higher up in the beds the shell assumes a larger size and more typical aspect. The Soldado shells measure about 15 mm. in width. This species was less abundant there than *V. planicosta*.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene.

Venericardia crucedemaionis new species. Plate VIII, Figure 14.

Description.—Shell small, cordate; substance thin and fragile; sculpture of (*a*) very narrow, elevated, radial riblets with much wider interspaces; riblets squamose at the posterior end of the valve and nodular-stellate over the central portion; (*b*) interradial striæ, one on each side of the basal part of the riblets at the anterior part of the shell; but entirely absent from the posterior end of the shell; characters of hinge concealed by the matrix.

Height of shell 6, length of portion exposed 7 mm.

Remarks.—This species is evidently closely related to *V. alticostata* Conrad, but differs in having two interradial striæ, one at the base of each side of the anterior riblets while *alticostata* has only one. This is also a much smaller and more delicate shell than Conrad's species.

It may be that if more specimens of Venericardias of the *alticostata* group are ever obtained from Soldado Rock, this species and the larger form, that the writer has described as *V. thalassoplekta*, may be found to be both strongly marked varieties of *V. alticostata*. In the material we have now, there are three forms—one which, though very small, answers perfectly in sculpture to Conrad's description of *alticostata;* the species described above; third, the larger form, *V, thalassoplekta*. Tentatively the two last mentioned are described as separate species. A shell varying in a similar direction from *planicosta* is figured by Professor Harris from the Lignitic of Alabama.[27]

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene. Equivalent to that of Alabama.

The specific name is given because of the shell's starry nodules. The Southern Cross in Venezuela is called *Cruce de Maio*, since in the month of May it attains its greatest splendor.

Venericardia planicosta Lamarck. Plate VIII, Figures 15, 16.

Venericardia planicosta Lamarck, Syst. des An. s. Vert., p. 123, 1801; Ann. du Mus., VII, p. 55, IX, pl. 31, fig. 10.

Venericardia (*planicosta*) Lamarck, Ann. du Mus., vol. IX, pl. 31, figs. 10, a, b, 1807.

[27] Bull. Am. Pal., vol. II, p. 247, pl. 11, fig. 1.

Venericardia planicosta Sowerby, Min. Conch., 1, pl. L, 1814.
Venericardia planicosta, Deshayes, Coq. Fos. des Envir. de Paris, 1, p. 142, pl. 24, figs. 1–3, 1824.
Venericardia planicosta Conrad, Jour. Acad. Nat. Sci. Phila., vol. VI, pp. 213, 214, 215, 1830.
Cardita planicosta Deshayes, Enc. Méth. Vers., II, p. 198, 1830.
Venericardia ascia W. B. & H. D. Rogers, Trans. Am. Phil. Soc., 2d ser., vol. V, p. 374, pl. 29, fig. 2, 1839.
Cardita densata Conrad, Jour. Acad. Nat. Sci. Phila., 2d ser., vol. I, p. 130, pl. 14, fig. 24, 1848.
Cardita planicosta Conrad, U. S. Mexican Boundary Surv., p. 161, pl. 19, figs. 2, a, b, 1857.
Cardita hornii Gabb, Geol. Surv. Cal. Paleont., vol. I, p. 174, pl. 24, fig. 157, 1864.
Venericardia planicosta var. *regia* Conrad, Am. Jour. Conch., vol. I, p. 8, 1865.
Venericardia mooreana Conrad, Am. Jour. Conch., vol. III, p. 190, 1867.
Venericardia planicosta Conrad (Heilp.), Proc. Acad. Nat. Sci. Phila., p. 366, 1880.
Venericardia planicosta Aldrich, Bull. 1, Geol. Surv. Ala., pp. 50, 53, etc., 1886.
Venericardia planicosta Smith and Johnson, Bull. 43, U. S. Geol. Surv., pp. 40, 44, 45, 50, 51, 1887.
Venericardia planicosta Kennedy, Proc. Acad. Nat. Sci. Phila., vol. 47, p. 145, 1895.
Venericardia planicosta Harris, Bull. Amer. Pal., vol. I, pp. 172, 173, pl. IV, fig. 13, 1896; Bull. Amer. Pal., vol. II, pp. 246, 247, pls. 9, 10, 1897; Geol. Surv. Louisiana, Rept. for 1899, p. 302, pl. 53, fig. 6.
Venericardia planicosta Dall, Trans. Wagner Inst., III, pp. 1418–1423, 1903.
Venericardia planicosta Osborn, Age of Mammals, p. 93, 1910.

Lamarck's original description.—"*Venericardia* (*planicosta*) oblique cordata, crassissima; costis planis integris; posticis granulatis."

Lamarck adds that this species is found at Grignon, France; in Piedmont, and in the vicinity of Florence, Italy.

Remarks.—Inasmuch as up to the present no true Eocene formations had ever been found in the Antillean region it was thought well to figure a shell and a mould of this well known and most typically Eocene species from Bed No. 2, Soldado Rock. In the face of this shell which Conrad termed the "Finger post of the Eocene" the writer feels confident that the Eocene age of the Soldado Bed No. 2 will pass unchallenged. For this species never occurs *in situ* except in formations of this age.

This is the first time that *Venericardia planicosta* has ever been reported from the Antillean region. And Soldado Rock is the only locality in that area in which it has yet been found. In spite of its great known range this is the most southern point from which it has ever been reported.

Venericardia planicosta was a common species in the Soldado Rock, Bed No. 2 fauna, as a number of young and adult shells were obtained. The full grown specimens show all the characters of this species from the southern United States. When complete the greatest width of the largest shells from Soldado must have been about 70 mm., while some of the young shells measure only 8.

The migrations of this species during the Eocene were most remarkable. It extends over northern France, Belgium, and England, but in Europe it is only found as far south as Piedmont, in northern Italy, about 45° N. Lat. It is very abundant in the southern United States, and a varietal form is even found in California in the Tejon beds. Thus it had an east and west range—in a direct line—of 6000 miles. Soldado Rock, about 10° N. Lat. is the furthest limit yet known of its migration towards the equator. The direct North and South distance from this Rock to northern Belgium is approximately 2650 miles. Dr. Dall[28] is persuaded that America is the center from which the group has been distributed.

[28] Trans. Wagner Inst. Science, III, pp. 1418–1423, 1903.

During the Midway stage, but especially during the Lignitic of the southern United States, *V. planicosta* showed a vast number of variations.[29] But at the close of the Eocene the species absolutely disappeared. No representation is found in the Oligocene, Miocene or Pliocene of North America. Curiously enough, however, the recent analogue of *V. planicosta* occurs only on the Pacific coast in warm waters.

Locality.—Bed No. 2, Soldado Rock, near the Serpents Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway beds of Alabama and of Rio Maria Farinha. State of Pernambuco, Brazil.

Venericardia thalassoplekta new species. Plate VIII, Figure 17.

Description.—Shell of moderate size, subcordate, convex; posterior end of valve concealed in a silicious matrix; anterior and central portion of left valve beautifully sculptured with (*a*) narrow, elevated ribs, which, beyond the anterior third of the valve, become nodular, (*b*) two less elevated, intercalary, smooth, rounded riblets, equalling one another in size but narrower than the ribs themselves.

Height 22 mm.

Remarks.—A single specimen of this fine shell was found. It is closely allied to *V. alticostata;* but differs in having the two interstitial riblets and in the ribs being quite smooth over the anterior part of the valve.

The specific name has been given because the sea by constantly striking on the reef has fortunately eroded it in such a way as to leave the fossils standing more or less in relief.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene.

Genus **CARDITA** (Bruguière, 1789) Lamarck, 1799.

Cardita (Carditamera) virginiæ new species. Plate IX, Figures 2, 3.

Description.—Shell rather small, elongate-elliptical, very inequilateral, beaks low, situated at the anterior fourth of the entire length of the valve; sculpture of fifteen or sixteen well defined ribs, which on the short anterior end of the shell are regularly and closely crenulated, but on the long, posterior part of the shell are smooth or nearly so; characters of the hinge concealed by the matrix.

Length of shell 13, height 7 mm.

Remarks.—This species is most closely allied to Dr. Dall's *Carditamera tegea* from the Oligocene of the Tampa silex beds and the Chipola marls of Florida.

It may, indeed, if more specimens are found, grade into a varietal form of that shell.

The presence of a species of *Cardita* and especially of one near of kin to a Chipola species strengthens the evidence already offered by other species that the horizon in which it was found is Upper Oligocene.

[29] See Harris, Bull. Amer. Pal., II, pp. 246–247, 1897.

Locality.—Southern main road just south of Pitch Lake, Brighton, Trinidad, in a yellowish-brown, ferruginous marl.

Geological horizon.—Oligocene, probably a rather late stage of that period.

Genus **CRASSATELLITES** Kruger, 1823.

Crassatellites sp. indet. Plate IX, Figure 4.

In the black shales near Coycuar, Venezuela, are a number of very small shells with the marked umbonal-basal carination, and strong concentric groovings characteristic of the young of *Crassatellites*.

They are therefore tentatively referred to this genus.

Locality.—On the trail from Parare to Coycuar, about six miles south of Parare and three south of Caituco, Venezuela.

Geological horizon.—Basal Upper Cretaceous?

Genus **CARDIUM** Linnæus, 1758.

Cardium (Trigoniocardia) carolinæ new species. Plate IX, Figures 5, 6.

Description.—Shell small, convex, triangularly cordate, anterior margin sloping in a rounded curve to the basal margin, posterior margin truncated; shell divided, by a prominent carina extending from the beak to the posterior end, into a body area and a truncated posterior area; ribs on the body nine, rather sharp-edged, ornamented by bead-like nodules which on the four ribs towards the carina are on the carina side of each rib, on the remaining five ribs the beads are nearly central; ribs on the truncated area eight, more crowded, less elevated, squamose rather than beaded; interspaces on the body much narrower than the ribs, except the space beside the carinal rib, which is wider than the others, and is beautifully and conspicuously marked by the cross striæ of lines of growth which also cross the other interspaces, but there are hardly seen except with a lens.

Height of shell 11, greatest width 7, diameter 8 mm.

Remarks.—This exquisite little shell is closely allied to Dr. Guppy's *Cardium castum* from the Manzanilla beds,[30] but that species has twenty-two stout rounded ribs, and the posterior slope near the beak is different. In general form also it has a resemblance to *Cardium maturense* Dall from the Pliocene of Matura, Trinidad, and to *C. aiminense* Dall from Santo Domingo Oligocene beds.

The species is dedicated to Mrs. Arthur C. Veatch, of Washington, D. C.

Locality.—Along the shore one thousand feet west of the pier at Brighton, Trinidad, in asphalt.

Geological horizon.—Upper Oligocene about Chipolan.

Genus **PROTOCARDIA** Beyrich, 1845.

Protocardia coycuarensis new species. Plate IX, Figure 7.

Description.—Shell of moderate size, nearly equilateral, subcircular in outline; posterior surface ornamented by fifteen radiating ribs; anterior sculptured only

[30] Quart. Jour. Geol. Soc. London, vol. XXII, p. 582, pl. XXVI, fig. 4, 1866.

with delicate, concentric lines; characters of interior of shell concealed by the matrix.

Length of shell 24, height 23 mm.

Remarks.—Gerhardt has described a *Protocardia* (*Protocardium elongatum*) from Peru characterized by elongated anterior end and nearly straight hinge line. Gabb also described a species of this genus from Pariatambo, Peru, which like this shell is more triangular, but is characterized by very coarse sculpture.

The original substance of this shell (which has been entirely removed by solution) was evidently exceedingly thin. This indicates that the conditions under which it lived were quiet and rather deep waters. This harmonizes also with the very fine grained shale in which it is found,—evidently formed some distance off shore and at considerable depths.

Locality.—On the trail from Parare to Coycuar, about six miles south of Parare, and three miles south of Caituco, in black shales.

Geological horizon.—Basal Upper Cretaceous?

Genus **MERETRIX** Lamarck, 1799.

Meretrix cf. nuttalliopsis Heilprin. Plate IX, Figure 8.

Heilprin's original description.—"Shell sub-elliptical, moderately ventricose, its surface covered with fine concentric striæ, which are apt to become roughly imbricate on the basal margin; umbones not very prominent, rather anterior; lunule cordate, deeply impressed at about its middle, its outline clearly pronounced by a sharply impressed line; posterior extremity regularly rounded, the anterior somewhat produced; margin entire; pallial sinus somewhat angular, pointing towards the center of the shell.

"Length 1½ inch."

Lignitic of Alabama, where it is very abundant.

Remarks.—Among the fossils from Soldado is a *Meretrix* which resembles in size, form, and concentric sculpture Heilprin's *nuttalliopsis;* but its state of preservation is too imperfect to admit of positive identification. It is, however, very probably this species or a varietal form.

Length of fragment 26, height about 25 mm.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene. Equivalent to that of Alabama.

Meretrix subimpressa Conrad.

Cytherea subimpressa Conrad, Jour. Acad. Nat. Sci. Phila., vol. I, p. 130, pl. 14, fig. 26.

Conrad's original description.—"Ovate, slightly ventricose, smooth and polished, with concentric, slightly impressed lines on the anterior side; anterior side short, rather acutely rounded; posterior side produced, acutely rounded at the extremity; dorsal margin long, oblique, slightly curved; beaks prominent; lunule lanceolate, defined by a slightly depressed line. Length 1⅛ in. Height .8 in.

"*Locality.*—Marlbourne, Hannover county, Virginia. Mr. Ruffin."

Meretrix subimpressa var. golfotristensis new variety. Plate IX, Figure 9.

Description.—A number of shells of a *Meretrix* were found in bed No. 8, Soldado Rock, which recall the varietal form of Conrad's *subimpressa*, found by Professor Harris in the Lignitic Eocene of Wood's Bluff, Alabama.[31] But the Soldado shells when compared with the Museum specimens from Wood's Bluff are seen to be smaller, less convex, more sculptured with concentric lines, and with the posterior margin still more prolonged, giving the general outline of the valve a more elliptical form.

The largest specimen measures in length 20, height 10, thickness of one valve 3 mm.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria (Golfo Triste of the early navigators).

Geological horizon.—Lignitic Eocene. Equivalent to the Lignitic of Alabama.

Genus **PITARIA** Römer, 1857.

Pitaria (Lamelliconcha) circinata Born. Plate IX, Figures 12, 13.

Venus circinata Born, Test. Mus. Vind., p. 61, pl. IV, fig. 8, 1780.
Venus rubra Gmelin, Syst. Nat., VI, p. 3288, 1792.
Cytherea juncea Guppy, Quart. Jour. Geol. Soc. London, XXII, p. 582, pl. XXVI, fig. 13, 1866.
Chione circinata Gabb, Geol. St. Dom., p. 250, 1873.
Pitaria (Lamelliconcha) circinata Dall, Trans. Wagner Inst. Science, vol. III, p. 1269, 1903.

Description.—Shell subequilateral, less trigonal and more circular in outline than is usual in this group, somewhat compressed; substance thin, rather delicate; surface handsomely sculptured with close-set, regular, sharp edged, concentric lamellæ; lunule small, narrowly cordate; escutcheon not defined.

Length of shell 10, height 8.5, diameter 4 mm.

Remarks.—Except in respect of size this shell is exactly like Dr. Guppy's *Cytherea juncea* from Cumana, Venezuela. It is no doubt a young specimen of this very interesting species. Dr. Dall says of *P. circinata*, "It is one of the very small number of *Veneridæ* which occur on both the Atlantic and Pacific coasts of middle America, and in harmony with this exceptional distribution also occurs in the Isthmian Oligocene."

This species has remained practically unchanged from Oligocene to recent times. It is akin to the characteristic Lower Oligocene *P. imitabilis* Conrad from Vicksburg, Mississippi.

P. circinata has been reported from the Oligocene of Panama (Gatun beds) and of Cumana, Venezuela; from the Pliocene of Trinidad; and is living on both coasts of Central America and in the Antilles.

Locality.—Along the shore 1000 feet west of the pier at Brighton, Trinidad, in an impure asphalt.

Geological horizon.—Upper Oligocene. Equivalent to the Chipolan stage of Florida.

[31] See Bull. Am. Pal., vol. II, p. 255, pl. 12, figs. 6, 7, 1897.

Pitaria (Lamelliconcha) labreana new species. Plate IX, Figures 14, 15.

Description.—Shell elongate-ovate, rather compressed, inequilateral, lunule small, well-defined, lanceolate; valve sculptured with narrow, round-edged lamellæ, with much wider grooves between them; hinge characters shown in the figure; pallial sinus very deep, rounded, broad, extending beyond the center of the valve.

Length of shell 17, height 13, diameter 6 mm.

Remarks.—This species is akin to *P. hilli* Dall from the Oligocene of Gatun on the Panama canal. It differs from the latter shell in having a bolder, more distally ribbed type of concentric sculpture, and, as far as shown, is much smaller.

Locality.—Along the shore 1000 feet west of the pier at Brighton, Trinidad, in an impure asphalt.

Geological horizon.—Upper Oligocene. Equivalent to the Chipolan stage of Florida.

Genus **CALLISTA** Poli, 1791.

Callista mcgrathiana Rathbun. Plate IX, Figure 10.

Callista McGrathiana Rathbun, Proc. Boston Soc. Nat. Hist., vol. XVII, p. 255, 1875.
Callista McGrathiana White, Arch. do Museu Nac. do Rio de Janeiro, vol. VII, pp. 95–96, pl. V, figs. 36, 37, 38, 1887.

Rathbun's original description.—"Shell small, elongate, and with the valves moderately convex; length somewhat greater than the height; outline subelliptical.

"The beaks are situated a little in advance of the middle, are prominent and incline rather strongly forward. Their internal moulds are sharply pointed and incurve slightly. The hinge margin descends quite rapidly from the beaks posteriorly, and is moderately curved, nearly the same curve being continued in the larger part of the posterior margin, while the ventral margin is also very regularly, but more gradually rounded.

"The point of greatest convexity of the valves is just above the middle, though the curvature of the surface from the beaks to the ventral margin is usually quite regular. The curvature along the antero-posterior diameter is moderate and more or less regular. The slope toward the posterior and hinge margins is usually quite rapid, and increases in strength near the beaks; it is always well rounded.

"The surface of the shell is marked with numerous small, rounded, concentric raised-lines, separated by similar interspaces of slightly greater width. They are quite equally disposed, sometimes, however, differing in width and placed nearer together. They round up strongly in front.

"The muscular imprints are of moderate size, slightly excavated, and are situated just above the antero-posterior axis. Of the cardinal teeth, the anterior is nearly perpendicular, bending slightly forward below, while the posterior, which is the longer, extends backward, bending a little downward. The dental prominence in front of the cardinal teeth is somewhat elevated.

"This small form, not represented by any perfect impression of the exterior,

seems to be a true *Callista*, as indicated by shape and hinge markings. Size: length 14 mm.; height 11 mm.; depth of two valves 6 mm.

"Moderately abundant in the Cretaceous beds at Pt. Nova Cruz and São José, Prov. of Pernambuco, Brazil. Respectfully dedicated to Dr. McGrath of Pernambuco, to whom Prof. Hartt and his party are indebted for many favors and valuable information regarding the geology of the vicinity of Pernambuco."

Remarks.—The specimens from Soldado Rock vary a good deal in size, from about 14 mm. in length (the size of Rathbun's type) to 21 mm. The locality was evidently very well adapted to the species which is quite common.

Dr. White records this species also from the Rio Maria Farinha beds, State of Pernambuco, and from Rio Piabas, State of Para.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Callista mcgrathiana Rathbun var. rathbunensis new variety. Plate IX, Figure 11.

Description.—Shell similar to a large specimen of *Callista mcgrathiana;* but characterized by the sudden cessation of the concentric groovings over the lower, central portion of the valve. Elsewhere the concentric sculpturing is beautifully regular, then it abruptly becomes obsolete.

Length of shell 21, height 15 mm.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and to that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

This variety is named in honor of Dr. Rathbun, of the United States National Museum, who was the first to describe shells from the Rio Maria Farinha beds, Brazil.

Subfamily VENERINÆ.

Genus **CHIONE** von Muhlfeld, 1811.

Chione veatchiana new species. Plate IX, Figures 17, 18.

Description.—Shell moderately small for the genus, ovate-triangular, slightly rostrated posteriorly; substance rather thin; hinge characters shown in the figure; pallial sinus short, triangular; inner margin of valves finely and sharply crenate; sculpture of close-set, feeble, very slightly raised lamellæ, cancellated by slightly more conspicuous, radiating striæ.

Length of shell 25, height 20, diameter 14 mm.

Remarks.—This species is allied to *Chione walli* Guppy[32] from the Manzanilla beds of Trinidad; but the outline of the latter shell is circular instead of elongately-triangular, and the concentric sculpture tends to be stronger than the radial, while in the species now described the opposite is true.

The shell is dedicated to Mr. Arthur C. Veatch, by whom it was collected.

Locality.—Along the shore 1000 feet west of the pier at Brighton, Trinidad, in impure asphalt.

[32] Quart. Jour. Geol. Soc., XXII, pl. XXVI, fig. 16, 1866.

Geological horizon.—Upper Oligocene. Equivalent to the Chipolan stage of Florida.

Chione dalliana new species. Plate IX, Figure 16.

Description.—Shell rather small for the genus, subcircular in outline; hinge characters concealed by the matrix; inner edge of valves finely crenulate; sculpture of regular, low concentric lamellæ crossed by very fine, close-set, radial striæ which with the lamellæ form a delicate cancellation over the entire surface; anteriorly the radial sculpture strengthens, forming about seven well marked plications.

Length of shell 20, height 17, diameter approximately 8 mm.

Remarks.—In general form and type of sculpture this species resembles Dr. Guppy's *Chione walli* from the Manzanilla beds of Trinidad; but it is at once distinguished from that species and from the other related forms described in this report by the very characteristic anterior radial plications.

The shell is dedicated to Dr. W. H. Dall, of the National Museum, Washington.

Locality.—Along the shore 1000 feet west of the pier at Brighton, Trinidad, in impure asphalt.

Geological horizon.—Upper Oligocene. About equivalent to the Chipola stage of Florida.

Chione guppyana new species. Plate IX, Figure 19.

Description.—Shell of moderate size, suborbicular, slightly obtusely pointed at the posterior end, sculpture of same general type as *C. veatchiana*,—that is, finely and delicately cancellated by the intersections of radiating threads with somewhat less pronounced, concentric lamellæ; interior margin finely and sharply crenate; pallial sinus quite deep and obtusely triangular; hinge characters as shown in the drawing.

Length of shell 19, height 16 mm.

Remarks.—This species is readily distinguished from *C. veatchiana* by its more circular outline and the striking differences in the form of the pallial sinus which in *veatchiana* is typical, but in *guppyana* rather deep and broad for the genus. From *C. dalliana* this species is distinguished by the absence of the characteristic seven or eight strong radial plications on the anterior end of that shell.

This species is dedicated to Dr. R. J. Lechmere Guppy, of Port of Spain, Trinidad.

Locality.—Along the shore 700 feet east of the Brighton pier, Trinidad, in impure asphalt.

Geological horizon.—Upper Oligocene. About equivalent to the Chipolan stage of Florida.

Chione paraensis White.

Venus (*Chione*) *paraensis* White, Arch. do Museu Nac. do Rio de Janeiro, vol. VII, pp. 94–95, pl. V, figs. 34, 35, 1887.

White's original description.—"Shell rather small, gibbous, transversely subelliptical in marginal outline; lunule moderately large, cordiform, prominent, distinctly grooved by a narrow, sharply impressed groove; escutcheon long, lanceolate, concave from side to side, bounded on each side by a distinct ridge which extends from the beak by a gentle outward curve, to the posterior border; umbones slightly elevated; beaks small, closely incurved upon the cardinal margin and turned forward; cardinal margin broadly and regularly convex; anterior and posterior margins regularly and almost equally rounded; basal margin broadly and regularly convex; cardinal teeth well developed; sublunular tooth comparatively strong. Surface marked by numerous sharply raised, finely crenulate, concentric lamellæ which cover the whole surface including the lunule but not including the narrow escutcheon. These lamellæ consist of merely close-set, raised striæ upon the beaks, but they become stronger and wider apart towards the free margins.

"Length 21 millimeters; height from base to umbones 18 millimeters."

Rio Piabas, State of Para, Brazil.

Chione paraensis White var. Plate IX, Figure 20.

A varietal form of Dr. White's *Chione paraensis* is rather common in the Soldado fauna. It differs from the type in its less convex form.

Length of largest shell 20, height 15 mm.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria, near the Serpent's Mouth.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and that of the Maria Farinha beds, State of Pernambuco, Brazil.

Genus **VENERUPIS** Lamarck, 1818.

Venerupis Lamarck, An. s. Vert., V, p. 506.
Venerupis Sowerby, Conch. Man., p. 113, 1839.
Rupellaria H. and A. Adams, Genera Rec. Moll., II, p. 437, 1857. Not *Rupellaria* of Fleuriau.
Venerupis Fischer, Man. de Conchyl., p. 1087, 1887.
Irus Herrmannsen, Ind. Gen. Mal., II, p. 684. Not *Irus* of Oken, Lehrb. der Naturg., pp. 230 848, 1815.

Venerupis atlantica new species. Plate IX, Figure 21.

Description.—Shell characterized by its very striking sculpture which consists of (*a*) sharp-edged, nearly regular and equidistant, thin, erect, concentric lamellæ, which are more elevated at the upper posterior margin; (*b*) radiating striæ which are very fine, close, nearly regular, and ornament the surface of the shell between the erect ridge-like lamellæ which the striæ do not cross; hinge lacking.

Height of fragment 10 mm.

Remarks.—This is the first species of *Venerupis* ever found in the fossiliferous beds of the eastern coasts of the Americas.

The genus now lives in all the European seas, and the Indian and the Pacific Oceans. It is not now represented in the Atlantic.

For this reason the specimen has been identified as *Venerupis* with some hesitation; but its resemblance to Fischer's figure of *Venerupis exotica*, and to Kobelt's figure of *V. irus* (the geno-type) is so striking that although, unfortunately, the hinge characters are not known, yet it cannot be any other genus. It does not resemble the *Petricolas*.

Apparently the genus *Venerupis* became extinct on the east coast of the Americas at the close of the Lignitic, just as *Cymia* died out at the close of the Oligocene. *Venerupis* is found in the California Pliocene and is now living on the coast of that state.

The oldest species of the genus are found in the Cretaceous.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Genus **MACTRA** Linnæus, 1758.

Mactra austeniana new species. Plate IX, Figures 22, 23.

Description.—Shell of moderate size; triangular, rather thin, moderately convex; beaks low, approximate; surface sculptured only by concentric lines of growth; pallial sinus small, rounded; hinge of right valve with a short double anterior lateral tooth, a strong bifid or reversed V-shaped cardinal, a triangular chondrophore (about equalling in size the bifid tooth), and a double elongated posterior lateral tooth; the narrow, lanceolate ligament area is separated from the chondrophore by a shelly plate.

Length of largest specimen 27, height 21, diameter 14 mm.

Remarks.—Small individuals of this species superficially recall *Mulinia lateralis* in their general outline; but the hinge characters are very different,—the shelly plate lying between the ligament and the chondrophore separating this shell at once from *Mulinia*.

This species seems to be more closely allied to true *Mactra, sensu stricto*, than to any of the other genera of the sub-family Mactrinæ.

We are enabled by this fact to add a further indication of the Oligocene age of the horizon. For according to Dr. Dall[33] typical Mactras are relatively modern and are not known in America from rocks older than the Oligocene.

Two suggestions are also given by this shell that the horizon it occurs in is late Oligocene. *First, Mactra, sensu stricto*, does not occur on the Pacific coast in the recent fauna, although there is one species still living in the Caribbean area. This suggests that the genus developed late in the Oligocene and its spreading westward was interrupted by the rise of the Isthmus. *Second*, there is also a true *Mactra* found in the Chipola marls (late Oligocene) of Florida, *Mactra chipolana* Dall.

The writer takes great pleasure in naming this shell in honor of Mr. Austen, Librarian of Cornell University. His kind help in matters of bibliography has greatly facilitated our researches.

[33] Trans. Wagner Inst. Science, vol. III, p. 892.

Locality.—Along the shore 1000 feet west of the Brighton pier, Trinidad, in an impure asphalt.

Geological horizon.—Upper Oligocene, about equivalent to the Chipola marls of Florida.

Genus **CORBULA** Bruguière, 1792.

Corbula (Cuneocorbula) helenæ new species. Plate IX, Figure 25.

Description.—Shell small, sub-equilateral, nearly equivalve; general form oblong-ovate, posterior slope carinate, posterior end truncate, anterior end broadly rounded; beaks low, approximate; concentric sculpture on both valves of numerous, close-set, more or less obsolete and feeble ribs; radial sculpture, especially on the left valve, of very fine, close striæ radiating from the beaks to the lower margin, most strongly developed near the carina.

Length 8, height 5, diameter 3 mm.

Remarks.—In general outline this shell is nearest to *Corbula* (*Cuneocorbula*) *sarda* Dall from the Chipola Oligocene of Florida, but *C. helenæ* is a shorter and more delicate shell.

The radiating striæ in *C. helenæ* are unusual in the genus, but occur in some species as *C.* (*Cuneocorbula*) *sericea* Dall from the Bowden Oligocene of Jamaica and in *C. lavalleana* Orbigny, of the recent Antillean fauna.

This shell is named in honor of Mrs. Alfred Schultz, of Washington, D. C.

Locality.—Along the shore at Brighton, Trinidad, 1000 feet west of the pier, in an impure asphalt.

Geological horizon.—Upper Oligocene, about equivalent to the Chipola horizon of Florida.

Corbula (Cuneocorbula) subengonata Dall. Plate IX, Figure 24.

Corbula engonata Aldrich, Bull. I, Geol. Surv. Alabama, p. 58, 1886. Not of Conrad, Proc. Acad. Nat. Sci. Phila., III, p. 294, 1848.
Corbula alabamiensis Lea var., Harris, Bull. Am. Pal., vol. II, p. 260, pl. 13, fig. 14, a, 1897.
Corbula subengonata Dall, Trans. Wagner Inst. Sci., vol. III, p. 841, 1898.
Corbula subengonata Clark and Martin, Eocene, Maryland Geol. Surv., p. 163, pl. XXXII, figs 1., a, 2, a, 1901.

Harris' description.—"This variety is by no means so large nor so inflated as *alabamiensis*, yet some specimens seem to indicate a transitional stage so far as form is concerned. From *Corbula engonata* this is distinguished by its more compressed form, smaller concentric lines and more rectilinear base" (1897). Type locality, Gregg's Landing, Alabama. Lignitic Eocene.

Dall's description.—"This form is smaller, less inflated, thinner, and with more nearly parallel dorsal and ventral borders than *C. alabamiensis.* The sculpture is finer than in *C. engonata;* which is a more elongated species" (1898).

Remarks.—On comparing one of our two species of *Corbula* from Bed No. 8, Soldado Rock, with a specimen of *engonata* from Gregg's Landing, the shells are found to match perfectly in size and shape. The only difference is that the concentric grooving is somewhat more distant, bolder, and coarser in the Soldado form.

Altitude of Soldado shell 6.5, length approximately 10.5 mm.

Locality.—This species is very common in the Eocene of Maryland and Virginia. Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Corbula (Cuneocorbula) weaveri new species. Plate IX, Figure 28.

Description.—Shell small, sharply carinate, subtriangular, not very convex, anterior end rounded, posterior end acutely pointed; sculpture of about five concentric, rather rounded ridges and alternate deep groovings.

Length of shell 8, height 5.5, thickness of one valve 2 mm.

Remarks.—In its general outline this shell is not unlike the Midway *C. subcompressa* Gabb; but the anterior slope is not rounded as in that species, and the sculpture is decidedly bolder in the Soldado form. Of the described Lignitic species, it is nearest *C. subengonata,* but is shorter and more triangular and more strongly sculptured.

This shell is named in honor of Mr. Paul Weaver, of Brooklyn, N. Y., who assisted Mr. Veatch in collecting at Soldado Rock.

Locality.—Bed No. 8, Soldado Rock, near the Serpent's Mouth in the Gulf of Paria.

Geological horizon.—Lignitic Eocene, about equivalent to the Nanafalayan.

Corbula (Bothrocorbula) smithiana new species. Plate IX, Figures 29, 30.

Description.—Shell small, nearly equilateral, very solid and thick, convex, with a very deep cavity in the interior, general form ovate, posterior slope carinate, posterior end pointed, slightly rostrate; anterior gently rounded; beaks low and small; sculpture of about twelve narrow, concentric, rather sharply edged ribs with wider interspaces extending from the basal margin to a short distance below the beaks which are nearly smooth. Only a single (left) valve was found.

Length of shell 8.5, height 5, diameter 6 mm.

Remarks.—This shell is of the general type of *C. viminea* Guppy from the Oligocene of Jamaica and Haiti, and like it belongs to Gabb's section *Bothrocorbula,* of which *C. viminea* is the type. Shells of this section of the genus are found in the Antilles from the Oligocene to the recent faunas. Two species extended northward to the Chipola and Oak Grove beds of the Florida Oligocene, and one species occurs in the Pliocene of the Caloosahatchie, Florida.

On comparing *C. smithiana* with Dr. Guppy's *viminea,* the latter is at once seen to be shorter, higher, more boldly sculptured, and is a much larger shell.

The species is named in honor of Captain Smith of the S. S. Viking, Port of Spain, Trinidad.

Locality.—On the shore at Brighton, Trinidad, 1000 feet west of the pier, in an impure asphalt.

Geological horizon.—Upper Oligocene, about equivalent to the Chipolan of Florida.

Corbula sp. indet. Plate IX, Figures 26, 27.

A number of moulds of the interior of a species of *Corbula* were found in the ferruginous marl south of Pitch Lake. It was evidently a common species.

In form the shell was of the short, high, very convex type; the moulds are nearly equilateral, rounded anteriorly, truncated posteriorly; with the two valves not differing much in size.

Length of mould 11, height 9, diameter 7 mm.

Locality.—Southern main road just south of Pitch Lake, Brighton, Trinidad.

Geological horizon.—Oligocene.

Genus **PHOLAS** (Lister, 1687), Linnæus, 1758.

Pholas mackiana new species. Plate IX, Figure 31.

Description.—Shell oblong-ovate, slightly inflated, small for the genus, thin and fragile; sculpture of concentric fluted lines of growth which at the anterior end of the valve are raised into close-set, radial riblets on which the fluting is more strongly marked than elsewhere; beyond the anterior end the concentric lines become more pronounced and are marked with V-shaped folds, while the radial sculpture is lost.

Height of shell 14 mm.

Remarks.—When compared with the Miocene species of *Pholas* from the southeastern United States, the Trinidad shell is found first to differ very markedly from *P. arcuata* Conrad. For in the latter species the radial sculpture is prominent all over the shell; and it is also much heavier and less fragile than *mackiana*. To *P. producta* Conrad and *P. memmingeri* Tuomey and Holmes, both South Carolinian species, the shell from Trinidad bears only a generic resemblance.

On comparing *P. mackiana* with living species, it is at once seen to be quite unlike the common *Pholas costata* Linn. that ranges from Massachusetts to Brazil. *P. costata* is the recent analogue of *P. arcuata*, and like the latter has radial sculpture all over the shell. But the Trinidad fossil does resemble in type of sculpture both *P. campechensis* Gmelin living in the southern United States and the West Indies, and *P. chiloensis* on the shores of Peru and Chile. These species, as Tryon has pointed out,[34] are very closely related and apparently almost identical, which is surprising because of their being east and west coast shells.

Now, as the writer is convinced, the key to the explanation of this resemblance of these east and west coast recent species is the Trinidad fossil. It represents the ancestral Oligocene stock from which both the recent forms started from a center of development in the lower Antilles. Before the rise of the Isthmus of Panama the western form migrated to the Pacific and has continued to develop there, while the eastern has been slowly spreading along the Atlantic coast.

Pholas mackiana thus furnishes a further indication of the Oligocene age of the asphaltic marl in which it was found.

[34] Mon. Pholadidæ, Proc. Acad. Nat. Sci. Phila., p. 76, 1862.

It is also interesting as the first undoubted[35] species of *Pholas* ever described from the Oligocene of either the Gulf States or the Antilles.

Locality.—Along the shore 700 feet east of Brighton pier, Trinidad Island, in an impure asphalt.

Geological horizon.—Approximately equivalent to the Chipola (Upper Oligocene) epoch of Florida.

This species is named in honor of Mr. John Mack, of Philadelphia.

Genus **MARTESIA** (Leach) Blainville, 1824.

Martesia oligocenica new species. Plate IX, Figures, 32, 33.

Description.—Shell rather small, ovate-oblong, inequivalve; anterior end short, roundly gaping, obliquely truncate; posterior end elongate, obtusely pointed; smaller valve lying within the posterior margin of the larger; furrow well marked, slightly oblique, placed near the anterior end of the valve; anterior surface sculptured with fine, slightly imbricated lines of growth.

Length of shell 14, height 8, diameter 7 mm.

Remarks.—This is the first undoubted species of *Martesia* yet recorded from the Oliogcene of the southern United States or the Antilles.[36]

It is evidently closely related to the recent and Pliocene species, *Martesia striata*, Linn., of which it may be an ancestral form. *M. striata* has been found in the Pliocene of Trinidad and Costa Rica.

Locality.—Southern main road just south of Pitch Lake, Brighton, Trinidad, in a yellowish-brown, ferruginous layer.

Geological horizon.—Upper Oligocene.

Class GASTROPODA.

Genus **CYLICHNA** Lovén, 1846.

Cylichna solivaga new species. Plate X, Figure 1.

Description.—Shell small, rounded cylindrical; substance thin; spire involute, sunken; surface of shell entirely smooth and unsculptured except for fine microscopic striæ over the lower basal fourth of the shell; other characters concealed by the matrix.

Height of shell 9.5, greatest diameter about 5 mm.

Remarks.—A single imperfect specimen of this species was found.

It is more convex than *C. sylværupis* Harris from the Alabama Lignitic and does not appear to be identical with any other species described from the lower Eocene horizons.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

[35] A shell from the Bowden beds of Jamaica was referred with a question by Dr. Guppy to this genus and described by him as *Pholas? sphæroidalis.* See also footnote 36.

[36] According to Dr. Dall *M. sphaeroidalis* Guppy from Jamaica is probably referable to another group.

Genus **TEREBRA** Adanson, 1757.

Terebra sp. indet. Plate X, Figure 2.

Remarks.—The impression of a fragment of what appears to have been a shell of *Terebra* was found in the ferruginous marls at Brighton.

The drawing is from a gutta-percha mould taken from the original.

The sculpture suggests such forms as varieties of *T. dislocata* Say and of *T. bipartita* Sowerby.

Locality.—Southern main road just south of Pitch Lake, Brighton, Trinidad, in a yellowish-brown, ferruginous layer.

Geological horizon.—Upper Oligocene.

Genus **PLEUROTOMA** Lamarck, 1799.

Pleurotoma guppyana new species. Plate X, Figure 3.

Description.—Shell small, fusiform, when complete, number of whorls known six; whorls ornamented by (1) a nearly central row of small, equidistant, rectangular nodules; (2) spiral threads revolving over the volutions on either side of the row of nodules, being most marked on the basal side; (3) a slightly elevated, subsutural ridge; (4) transverse lines of growth which swing far back at the nodular rows, making angular curves and forming an oblique cancellation with the spiral threads.

Length of fragment 9, greatest width 5 mm.

Remarks.—The close relationship of this shell to the group of *Pleurotoma denticula* (Basterot) Edwards is at once apparent. It is very near to specimens from the Lignitic of Alabama described as *Pl. denticula* var. by Professor Harris,[37] from which it differs some in outline and in the presence of the subsutural ridge; but the type of sculpture is very like that of the Alabama shells.

Pleurotoma denticula was originally described from the southwest of France by Basterot.[38] Later, in 1860, Edwards referred a number of varying forms found in the Barton beds of southern England to varieties of this species, and Professor Harris has found certain varietal forms from England grade into those in the Alabama Lignitic. It is now of interest to find a type closely allied to the Alabama forms so far south as approximately 10° N. Lat.

The writer takes great pleasure in dedicating this species to Dr. R. J. Lechmere Guppy, of Port of Spain, Trinidad, whose unremitting interest, enthusiasm and careful study has done so much to further the world's knowledge of the paleontology of the Antilles.

Locality.—Bed No. 6, Soldado Rock, Gulf of Paria, near the Serpent's Mouth.

Geological horizon.—Lignitic Eocene.

[37] Bull. Am. Pal., vol. III, pp. 12–13, pl. i, fig. 21, 22, 1899.

[38] Descr. Géol. du Bass. Tert. Sud-ouest de la France, p. 63, pl. 3, fig. 12, 1825.

Genus **OLIVA** Bruguière, 1789.

Oliva trinidadensis new species. Plate X, Figure 4.

Description.—Shell rather small, characterized by being more pyriform and less cylindrical than is usual in the genus; whorls three, convex; suture deeply impressed, narrowly channelled; base of shell slightly notched; characters of pillar and aperture concealed by the ferruginous matrix.

Height of shell 15, greatest width 8 mm.

Remarks.—In its breadth of shoulder and tapering base this species resembles the much larger, recent *O. fusiformis* Lamarck, but it is still broader proportionally and widens more suddenly than that shell.

Dr. Guppy in his list mentions *O. cylindrica* Sowerby from the Caroni beds of Trinidad, and *O. reticularis* from Jamaica, *ispidula* and *cylindrica* from Haiti. The latter Dr. Dall[39] places in synonymy with *O. litterata*, and also remarks that *ispidula* is quite possibly a variety of *litterata*.[40]

These species are all of a cylindrical outline, quite unlike the shell described above.

Locality.—Southern main road just south of Pitch Lake, Brighton, Trinidad.

Geological horizon.—Upper Oligocene.

Genus **MARGINELLA** Lamarck, 1801.

Marginella dalliana new species. Plate X, Figures 5, 6.

Description.—Shell of moderate size, rather solid and strong, subpyriform; whorls four; spire very short, nearly entirely enrolled by the last volution; sides of shell convex; evenly rounded; outer lip in adult specimens much thickened along the margin, not lirate, marked off by an impressed line behind it; aperture wide for the genus, especially toward the anterior; inner lip with only a very light callus; columellar plaits four, of which the two anterior are very oblique, the two posterior only slightly so, or nearly horizontal.

Height of shell 20, greatest breadth 13, length of aperture 18 mm.

Remarks.—In its general form this species is not unlike Dr. Dall's *M. ballista* from the Tampa silex beds, of the Florida Oligocene,—only that shell has a decided compression at the central part of the outer lip, and the four columellar plaits all sloping at about the same angle.

Dr. Guppy's *M. coniformis*, from the Oligocene of Jamaica and Haiti, is also of somewhat the same form; but is a much slenderer shell with the outer lip slightly lirate, and the aperture much narrower.

The writer takes great pleasure in naming the Trinidad species in honor of Dr. W. H. Dall of the Smithsonian Institute, Washington, D. C., as a slight token of appreciation of his invariable kindness and helpful suggestions during many years.

Localities.—Along the shores at Brighton, Trinidad, 1000 feet west of the pier, and also 700 feet east of the pier, in an impure asphalt.

[39] Trans. Wagner Inst., III, p. 44.
[40] *Loc. cit.*, p. 45.

Geological horizon.—Upper Oligocene, about equivalent to the Chipola marls of Florida.

Genus **CARICELLA** Conrad.

Caricella ogilviana new species. Plate X, Figure 7.

Description.—Shell of moderate size, thick and strong as shown where it is fractured; whorls six, sloping evenly from a short, acute spire, last volution not at all shouldered, gently rounded; sutural line inconspicuous, surface of shell entirely smooth, lines of growth very faint, seen only with a lens; plaits of the columella concealed by the silicious matrix.

Length of shell 25, greatest width 14, thickness 12 mm.

Remarks.—This species is entirely unlike any known *Caricella* from the lower Eocene horizons. Its general form, however, is considerably like *Caricella isabellæ* Maury from the Oligocene of Florida. One specimen only was found.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Named in honor of Dr. Ida H. Ogilvie, of Barnard College, Columbia University.

Caricella perpinguis new species. Plate X, Figure 8.

Description.—Shell medium sized; pyriform, solid and strong, as shown by the thickness of the fractured lip; whorls six, sloping rather suddenly from a short, very acute spire; last volution extremely convex and inflated; sutural line distinct, impressed; surface of shell entirely smooth, lines of growth visible only with a lens; plaits of the columella concealed by the silicious matrix.

Length of shell 29, greatest breadth 17, thickness 15 mm.

Remarks.—Only a single shell was found also of this *Caricella*, which can at once be distinguished from *C. ogilviana* by the decided difference in outline. When placed side by side *C. ogilviana* is comparatively slenderly and gracefully proportioned, while *C. perpinguis* as its name implies, is an exceedingly robust shell. The number of whorls is the same in both shells, which precludes the possibility of one being a younger form.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene.

Caricella sp. indet. Plate X, Figure 9.

Among the collection of fossils from Soldado is a portion of the spire of a shell which belongs in or near the genus *Caricella*. This is indicated by the peculiarity of its sculpture. All the whorls exposed are perfectly smooth, except that at the top of the spire which show very distinct traces of fine, very oblique, longitudinal riblets.

This character, as Dr. Dall has shown in his review of the *Volutidæ*,[41] is typical of the *Caricella* group of the *Voluta* family.

[41] Trans. Wagner Inst. Science, vol. III, pp. 57–91.

The Soldado shell has these plications unusually oblique, otherwise the spire resembles those of specimens of *C. heilprini* from the Lignitic of Wood's Bluff, Alabama. The single example from Soldado is, unfortunately, too imperfect for any positive identification or description.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Genus **VOLUTILITHES** Swainson, 1840.

Volutilithes pariaensis new species. Plate X, Figure 10.

Description.—Shell broadly fusiform; spire acute, about one-third the total height; whorls eight, of which the first two are minute, smooth, nuclear, the following sculptured by rather delicate spiral striæ and more marked longitudinal riblets (six in the dorsal side of the last volution), riblets interrupted especially on the body whorl by a large subsutural spiral groove which gives a very pretty coronate or beaded appearance; columella entirely concealed by a silicious matrix.

Height of shell 18, greatest width 9 mm.

Remarks.—This shell exhibits the general features of sculpture of *V. rugata* Conrad[42] from the Midway of Texas and Alabama. Indeed, the writer is in doubt whether it should not be placed as a variety of that species. Yet on comparing with a large number of specimens of *rugata* it is so unlike them in form, so much broader and shorter, that it is finally left tentatively as a separate species. The Soldado shell in outline is like *V. saffordi*[43] which Professor Harris regards as a variety of *rugata.*[44] But the type of Gabb's shell is only part of the body whorl and too fragmentary for positive comparisons. It was obtained from the Midway of Tennessee, and, as far as one can judge, was very similar to the Soldado shell.

Locality.—Bed No. 2 Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene.

History of the genus.—Dr. Dall[45] makes some interesting remarks on the history of *Volutilithes.* It began during the Cretaceous, and reached its greatest development in the Eocene. After a period it gradually decreased in number of species, until only one typical species (*V. philippiana* Dall), and a second belonging to another section (*V. abyssicola* Ad. & Reeve) are known in the living state. Both are found in deep water where they appear as remnants of a fauna which has become mostly extinct in shallow water.

Volutilithes whitensis new species.

Volutilithes radula White, Arch. do Museu Nac. do Rio de Janeiro, vol. VII, pp. 126–127, pl. X, figs. 15–17, 1887. Not of Sowerby, Forbes (1846), nor Stoliczka, 1868.
Volutilithes radula Arnold (in Branner's report), Bull. Museum Comp. Zoology, Harvard College, vol. XLIV, p. 16, 1904.

[42] Jour. Acad. Nat. Sci. Phila., vol. IV, p. 292, pl. 47, fig. 32, 1860.
[43] *Fasciolaria saffordi* Gabb, Jour. Acad. Nat. Sci. Phila., vol. IV, p. 390, pl. 68, fig. 6, 1860.
[44] Bull. Amer. Pal., I, pp. 187–198, 1896.
[45] Trans. Wagner Inst. Science, vol. III, p. 74.

White's description.—"Shell elongate-subovate; spire less than one-third the total length of the shell; volutions six or more in number, convex, marked by moderately strong longitudinal varices, which are crossed by narrow revolving depressions, or grooves, the broadest one of which is at the distal side, near the suture. These grooves usually give the varices a distinctly crenulated aspect, and sometimes the crenulations are so prominent as to appear subspinous. The varices upon the last volution are long, but they become obsolete before reaching the beak, that portion of the shell being marked only by coarse revolving raised lines; beak somewhat narrow; aperture elongate, acute posteriorly, and ending anteriorly in a narrow, short, slightly deflected canal; outer lip thin; inner lip bearing two well defined folds.

"Length 22 mm.; breadth of the last volution 10 mm." These are the dimensions of the example figured on Plate X. Some of the examples in the collection are fully one-third larger than this.

The Brazilian collections contain a considerable number of examples of this species, but most of them are imperfect.

Remarks.—As later studies have shown that this Brazilian shell is not identical with the Cretaceous species from southern India that was identified by Forbes and Stoliczka with Sowerby's *radula*, the writer would suggest naming the shell in honor of Dr. C. A. White, as a token of his great contribution towards our knowledge of the Brazilian Cretaceous and Tertiary faunas.

As will be seen by the description given above, this shell has much in common with *V. rugata* Conrad, of the Midway Eocene of Texas and Alabama.

Locality.—Olinda and the Rio Maria Farinha beds, and also at Ponto das Pedras, all three localities being in the State of Pernambuco, Brazil.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and to that of bed No. 2, Soldado Rock, Gulf of Paria.

Volutilithes sp. indet. Plate X, Figure 11.

A small and very fragmentary shell, apparently a young *Volutilithes*, was found at Soldado in the Lignitic horizon. It is too imperfect to identify or describe; but on comparing it with young shells of *V. petrosus* from the Lignitic beds of Wood's Bluff, Alabama, it shows considerable resemblance to them.

Height of shell 13 mm.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Genus **LYRIA** Gray, 1847.

Lyria wilcoxiana Aldrich.

Lyria? sp. Dall. Trans. Wagner Inst. Science, vol. III, p. 69, 1890.
Lyria wilcoxiana Aldrich, Geol. Surv. Alabama, p. 243, pl. 12, fig. 4, 1894.
?*Lyria wilcoxiana* Harris, Bull. Am. Paleont., vol. I, p. 199, pl. 8, fig. 5, 1896.

Aldrich's original description.—"Shell rounded fusiform, whorls four, spire blunt, first three whorls smooth, body whorl transversely ribbed, the ribs rather

sharp with concave spaces; no spiral sculpture shown; suture distinct, not deeply impressed; body whorl long, terminating in a canal, which is missing in specimen figured; aperture long and narrow, inner lip showing a few plications, but the aperture is filled in so that the lips are almost completely hidden."

Type locality in or near McConnico's plantation, Wilcox County, Alabama. Midway Eocene.

Remarks.—In view of the columellar plaits on *L. wilcoxiana* and on the variety *aldrichiana* it seems doubtful whether the specimen from near Midway, Alabama, mentioned by Professor Harris[46] is this species. As far as could be determined, the columella of that shell was smooth.

Lyria wilcoxiana Aldrich **var. aldrichiana** new variety. Plate X, Figures 12, 13.

Description.—The Soldado shell although a varietal form is apparently the most perfect specimen of this species ever found.

It shows distinctly six, short well marked plications on the columella. These were obscured in Mr. Aldrich's type by the matrix.

The Soldado form differs from Mr. Aldrich's description in not having a distinctly marked suture, and especially in the fact that the plications extend only over the dorsal half of the last whorl. This peculiar characteristic is well illustrated by the figure.

The writer takes pleasure in naming this variety for Mr. T. H. Aldrich, of Birmingham, Alabama, by whom the species was described.

Height 23, greatest diameter 14 mm.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the Rio Maria Farinha beds in Brazil.

Genus **LEVIFUSUS** Conrad.

Levifusus pagoda Heilprin. Plate X, Figure 14.

Pleurotoma pagoda Heilprin, Proc. U. S. Nat. Museum, vol. 3, p. 149, fig. 1, 1880.
Fusus pagodiformis Heilprin, Proc. Acad. Nat. Sci. Phila., p. 375, 1880.
Fusus pagodiformis Aldrich, Geol. Surv. Alabama, Bull. 1, p. 55, 1886.
Levifusus pagoda var. Harris, Bull. Am. Pal., vol. I, p. 207, p. 19, fig. 8, 1896.
Levifusus pagoda Harris, Bull. Am. Pal., vol. III, p. 51, pl. 6, fig. 10, 1899.

Heilprin's original description.—"Ventricose; whorls about nine, the body whorl nodulated on the most convex portion (nearly central), the nodulations consisting of a single series of sharp, obtusely pointed, and flattened spines or nodes which frequently appear double by the crossing of an impressed line over their basal portion; upper volutions with a similar series of nodes almost immediately above the sutural line, and gradually dividing off into a crenulation, upper surface of the whorls concave, faintly striated, the sinual rugæ indicating but a faint sinus; lower surface with numerous well developed revolving lines, which show a tendency to alternate. Aperture exceeding the spire in length, considerably contracted at about its center.

[46] Bull. Am. Pal., I, p. 199, pl. 8, fig. 5, 1896.

"Length 1½ inch.

"*Geological horizon.*—Eocene of Alabama."

Remarks.—A single specimen of this striking species was found by Mr. Veatch at Soldado Rock. It is fragmentary and eroded, but can easily be recognized by its peculiar and characteristic aspect. In the Soldado shell the sharp spines are very prominent, and (as in the type) developed on the most convex portion of the whorls some distance above the suture.

The Soldado form was evidently unusually large and heavy, for the fragment has an altitude equal to that of the entire shell from Alabama.

This species is found in the Midway and Lignitic horizons of Alabama.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and to that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Genus **FUSUS** (Klein, 1753) Lamarck, 1801.

Fusus colubri new species. Plate X, Figure 18.

Description.—Shell small, very slender, fusiform; number of whorls known four; longitudinal sculpture of narrow, well-marked riblets (about ten on the last volution), and of fine lines of growth, visible only with a lens; transverse sculpture of spiral threads which are more distant from one another and more prominent where they revolve over the riblets of the body whorl; aperture small, rounded; canal very straight, long and slender.

Height of incomplete shell 25, greatest width 10 mm.

Remarks.—The slender, elongated form of this shell recalls such species as *Fusus meyeri* Midway variety, and *F. ottonis* Aldrich from the Alabama Lignitic Eocene, but the whorls of both those shells are carinated.

The nearest analogue of the Soldado shell is Dr. White's *F. longiusculus* from the Rio Maria Farinha beds, Brazil. That has the same uncarinated, convex whorls and apparently the same number of riblets; it also corresponds nearly in size. The difference is chiefly in the transverse sculpture, the spiral threads in the Brazilian shell being more pronounced and much further apart.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene.

Fusus bocarepertus new species. Plate X, Figure 17.

Description.—Shell rather short and broadly fusiform; number of whorls not known, the single specimen being very imperfectly preserved; the distinguishing characteristic is the regular, spiral, rather distant, grooving, which ornaments the surface of the shell; longitudinal sculpture of subequal rounded riblets, about six on the last volution.

Height of incomplete shell 20, greatest width 12 mm.

Remarks.—Though not greatly resembling the typical forms of *Fusus subtenuis* Heilprin, this species is quite like in general form specimens in the Cornell

Paleontological Museum of a variety of Heilprin's species from the Lignitic of Alabama. But instead of a series of groovings that shell has raised flattened threads.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria, near the southern Bocas. Hence the name.

Geological horizon.—Lignitic Eocene.

Fusus bocaserpentis new species. Plate X, Figures 15, 16.

Description.—Shell of moderate size, stout, broadly fusiform, number of whorls known seven, earlier whorls eroded; transverse sculpture of (*a*) undulate, nodular costæ (seven on half of the body whorl), developed on all the whorls, but only on the most convex portion of the last, where they become obsolete above and below, and (*b*) of irregular, wavy lines of growth; spiral sculpture of coarse, subequal revolving liræ; the latter intersect the finer lines of growth and give the surface of the shell when viewed under a lens a reticulated appearance; sutural lines not impressed, angulated; upper portion of whorls rendered concave by a broad, shallow subsutural sulcus.

Height of spire 35, greatest diameter 22 mm. Length of canal not known.

Remarks.—This shell is unlike any described from the Midway beds of either the United States or Brazil.

The only species at all of the same general outline and type of sculpture is *Fusus harrisi* Aldrich[47] from the Lignitic Eocene of Gregg's Landing, Alabama; but that is a smaller shell with only about half as many ribs and with much weaker revolving liræ.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Fusus longiusculoides new species. Plate X, Figure 19.

Description.—Shell small, slender, fusiform, number of volutions known four; longitudinal sculpture of rounded ribs (eight on the penultimate whorl), which extend from suture to suture; spiral sculpture of sharply-defined, equidistant threads of which there are six on the next to the last volution; canal straight; other characters of the aperture lacking.

Height of fragment 12, greatest width 5 mm.

Remarks.—This shell resembles in its general form and type of sculpture Dr. White's *Fusus longiusculus* from the Midway beds of Maria Farinha, Brazil. It is also akin to our Soldado Midway species, *Fusus colubri*.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Fusus meunieri new species. Plate X, Figure 20.

Description.—Shell small when complete, rather broadly fusiform; number of whorls known four, very convex, slightly angulated; longitudinal sculpture of

[47] Bull. Amer. Pal., vol. I, p. 64, pl. 4, figs. 2 and 8, 1895.

narrow, rounded riblets of which there are eight on the last volution; transverse sculpture in the convex part of the whorls of rather coarse spiral threads, between which revolve sets of about five very delicate striæ visible only with a lens; elsewhere the striæ are fine and subequal.

Height of fragment 18, greatest width 10 mm.

Remarks.—In the rather sudden increase in diameter of the body whorl this species recalls the outline of *Fusus subtenuis* Heilprin[48] from the Lignitic Eocene of Alabama, but the type of sculpture is wholly different. For a sculpture resembling that of *F. meunieri* we must turn to *F. interstriatus* Heilprin also from the Lignitic Eocene of Alabama. In that species there is a similar intercalation of groups of fine striæ between coarser threads, but it is all over the surface of the shell, and not merely, as in the Soldado shell, on the regions of greatest convexity of the whorls.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth in the Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and to that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Named in honor of Professor Stanislaus Meunier, Musée d' Histoire Naturelle, Paris, as a souvenir of delightful hours spent in geologizing with him in the fields and forests of France.

Fusus mohrioides new species. Plate X, Figure 21.

Description.—Shell of moderate size, known whorls four; ornamentation of transverse, almost spinous nodules, strongest on the penultimate volution where there are about ten, apparently becoming obsolete on the body whorl; and of spiral threads of which three more pronounced than the rest revolve over the rows of nodules.

Height of fragment 22, greatest width 16 mm.

Remarks.—The single specimen of this shell obtained from Soldado is so imperfect that at first it seemed better not to found a new species upon it. But an examination showed that certain well defined characters were still retained even in its fragmentary condition.

These characteristics ally it rather closely with Mr. Aldrich's *Fusus mohri.*[49] The figure of that shell does not represent its sculpture at all well, but on comparing the Soldado form with specimens of *mohri* from the Lignitic Eocene of Matthew's Landing, Alabama, the nodules of the two shells almost match, and the increase in thickness of the three or four spiral threads, when they revolve around the rows of nodules, is also very marked in the Alabama shell. The species are certainly nearly related, though probably specifically distinct.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene.

[48] Proc. Acad. Nat. Sci. Phila., p. 371, pl. 20, fig. 4, 1880.
[49] Bull. Am. Pal., vol. I, p. 64, pl. 3, fig. 6, 1895.

Fusus sewalliana new species. Plate X, Figure 22.

Description.—Shell rather large, original shape fusiform, number of known whorls four; surface of shell handsomely sculptured by (*a*) longitudinal ribs, of which there are ten on the last volution, these extend from the broad and shallow subsutural sulcus to the succeeding suture or, on the last whorl, almost to the beginning of the anterior canal; (*b*) by rather regular longitudinal lines of growth; (*c*) by narrow, rounded spiral ridges which are more widely separated from one another where they revolve over the most prominent part of the longitudinal riblets; sutural line not well defined, wavy.

Length of fragment 40, greatest width 20 mm.

Remarks.—This species is unlike any known Fusidæ from the Midway of either North America or Brazil. In general form and type of sculpture it recalls *Fusus mortoni* var. *mortoniopsis* Gabb from the Lower Claiborne Eocene of Texas; but the Soldado shell is much larger and a more elegantly sculptured shell.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and to that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

The writer takes great pleasure in naming this shell in honor of Mr. Arthur Sewall, of Philadelphia, in appreciation of his very great interest in the scientific results of the Venezuelan Expedition.

Fusus sirenideditus new species. Plate X, Figure 23.

Description.—Shell large and strong with a thick and heavy columella; the single specimen is very imperfectly preserved, but is sufficiently striking to merit description; sculpture consisting of fairly coarse longitudinal lines of growth, interrupted by strong, narrow, revolving, spiral ridges (eight on the lower three-quarters of the last volution); above these the shell is somewhat shouldered and bears a few nearly obsolete longitudinal plications; those on the penultimate whorl are developed into well-marked, nodular riblets.

Height of fragment 40, greatest width 23 mm.

Remarks.—This species, which, when perfect, must have been a fine shell, seems to be quite unique in its characters among the lower Eocene faunas.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria. Hence the dedication to the Siren of the Rock.

Geological horizon.—Midway Eocene.

Fusus tæniensis new species. Plate X, Figure 24.

Description.—Shell rather small, short, fusiform; number of whorls exposed, three; sculpture of (*a*) coarse, close-set, regular, sub-equal, revolving, spiral threads which cover the entire surface of the shell; (*b*) well marked, nearly equi-distant, longitudinal wave-like riblets, of which there are five on the exposed half of the last volution; canal straight.

Height of incomplete shell 15, greatest width 10 mm.

Remarks.—At the first glance this shell might be taken for the species which was found accompanying it, *F. bocarepertus;* but the character of the sculpture differentiates them.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Genus **CLAVELLA** (Swainson, 1835) Agassiz, 1846.

Clavella harrisii new species. Plate X, Figure 25.

Description.—Shell rather solid, fusiform, spire and anterior canal long, tapering nearly equally to acute apices; number of known whorls, five; body whorl with only the faintest suggestions of obsolete longitudinal folds, penultimate whorl also nearly smooth, but the whorl preceding that is sculptured with about eight strong nodular costæ; these are also present on the two whorls next above; the third, fourth and fifth whorls (counting upwards) are ornamented with fine, rather regular spiral threads, which are not present on the body and penultimate volutions; these are marked only by lines of growth, and are quite strongly carinated by a broad, subsutural sulcus, which makes the upper part of these two whorls concave.

Height of the single fragment found 29, greatest width 14 mm.

Remarks.—No *Clavella* at all resembling this has yet been found in the Midway Eocene of the southern States.

C. kennedyanus[50] was described by Professor Harris from the Lower Claiborne of Texas, and was later found by him in the Lignitic of Alabama. This bears a considerable resemblance to the Soldado form, but the two latter whorls are evenly rounded, not carinated. The genus came in with the Eocene and flourished during that period. It has since constantly diminished, until at present there is but a single species in existence. This is *C. serotina* Hinds, living in the Polynesian waters.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and to that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

The writer takes much pleasure in naming this species in honor of Professor G. D. Harris, of Cornell University.

Clavella hubbardanus? Harris. Plate X, Figure 26.

Fusus hubbardanus Harris, Bull. Am. Paleont., vol. I, p. 201, pl. 8, figs. 10, 11, 1896.

Harris' original description.—"General form and size as indicated by the figures; whorls at least 10; ornamented by (*a*) spiral lirations, about five very strong ones below the shoulder, with an equal number of fainter alternate striæ, and five or six faint ones above, growing fainter as they approach the suture; (*b*) by obtuse nodular costations, 14 on the penultimate whorl strong at the shoulder but dying out rapidly above, less rapidly below; lines of growth fine

[50] *Clavilithes kennedyanus* Proc. Acad. Nat. Sci. Phila., p. 73, pl. 7, fig. 8, 1895.

but well marked, especially on the body whorl. On the last mentioned whorl the nodular costæ are faint and confined to the humeral angle; the spiral lirations below, about 10 in number, are strong; columella long, straight. Suture more or less filled by a revolving ridge."

Midway of Mississippi and Alabama.

Remarks.—A fragment of a large fusoid shell, probably *Clavella hubbardanus* was found at Soldado. It shows the characteristic rather faint longitudinal costæ on the humeral angle of the body whorl, and the general form proves that the Soldado shell was either identical with or closely allied to the Mississippi and Alabama species.

The illustration is of Professor Harris' type specimen from Mississippi.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene.

Genus **LATIRUS** Montfort, 1810.

Latirus tortilis Whitfield. Plate XI, Figure 1.

Fusus tortilis Whitfield, Am. Jour. Conch., p. 260, pl. 27, fig. 5, 1865.
Fusus tortilis Harris, Bull. Amer. Paleont., vol. I, p. 203, pl. VIII, fig. 14, 1896.

Whitfield's original description.—"Shell elongate, fusiform; spire slender, especially in the upper part, consisting of seven or eight sub-angular volutions, each marked by six strong longitudinal folds or varices, which are spirally arranged, those of one volution being a little behind the corresponding one of the preceding volution, the whole making about one-fourth of a turn in the length of the spire; canal long and straight, making, with the narrow, ovate aperture, rather more than one-half of the entire length; surface marked by somewhat alternating revolving lines, strongest on the largest part of each volution.

"*Dimensions.*—Length 1.75 inches, transverse diameter .7 inch.

"*Locality.*—Nine miles below Prairie Bluff, Alabama."

Remarks.—The single shell from Soldado, although eroded and imperfect, shows the general form and traces of the characteristic spiral striæ of *L. tortilis.*

On comparing the specimen from Soldado with shells of this species from the Alabama, Georgia and Mississippi Midway it is seen that the Soldado form tends to be somewhat larger, and broader across the last volution, with the sculpture rather bolder and more angular. In the latter respect it approaches the Lignitic variety *nanafalina* Harris from Alabama. But the typical form of *L. tortilis* sometimes as at Matthew's Landing, Alabama, developed during the Lignitic into larger and heavier shells than that from Soldado. Hence there seems no doubt that it is the same species.

Height of Soldado fragment 23, greatest width 13 mm.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and to that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Genus **FUSOFICULA** Sacco.

Fusoficula juvenis Whitfield. Plate XI, Figures 2, 3.

Pyrula juvenis Whitfield, Am. Jour. Conch., vol. I, p. 259, 1865.
Pyrula multangular Heilprin, Proc. Acad. Nat. Sci. Phila., p. 374, pl. 20, fig. 2, 1886.
Pyrula juvenis Aldrich, Geol. Surv. Alabama, p. 25, pl. 6, fig. 8, 1886.
Pyrula juvenis Harris, Bull. Am. Pal., vol. I, pp. 216–217, pl. 10, figs. 5, 6, 1896.
Fusoficula juvenis Harris, Bull. Am. Pal., vol. III, pp. 66–67, pl. 8, figs. 15, 16, 1899.
Fusoficula juvenis Clark and Martin, Eocene, Maryland Geol. Surv., p. 143, pl. XXIV, figs. 4, 4a, 1901.

Whitfield's original description.—"Shell small and fragile; spire elevated; columella slender, slightly bent; aperture large, elongate, ovate or subelliptical; volutions three, marked on the periphery by three distinct carinæ or subangular revolving ridges, the upper one marked with closely arranged longitudinally elongated nodes, the others simple; entire surface marked by very fine revolving lines, which are somewhat fasciculate below the lower carina, there being three finer ones between each larger one."

Type locality, six miles above Claiborne, Alabama.

Remarks.—This is a remarkably protean species, varying from three to four or with even traces of a fifth carina, and from simple carinate to crenulate forms.

The Soldado shells show no crenulations; in one there are three strong carinæ, in another three nearly obsolete carinæ, in still another the carinæ are entirely absent, the shell sloping up gently and evenly to the base of the spire. The lines of growth are prominent on all the Soldado shells, equalling in strength the spiral striæ, with which they form a beautiful cancellation over the entire surface.

Height of largest specimen 19, greatest width 7 mm.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Genus **STREPSIDURA** Swainson, 1840.

Strepsidura ? soldadensis new species. Plate XI, Figure 4.

Description.—Shell solid, pyriform, spire rather short, diminishing rather abruptly in diameter above the last volution; whorls about five, all ornamented with longitudinal costæ (about eight on the penultimate whorl) which, on the shoulder of the last volution, were angulated or perhaps slightly spinous; surface of the exterior of the shell covered with revolving spiral threads, fine and close set on the earlier whorls, but becoming more distant and prominent on the body whorl.

Height of fragment 24, greatest width 20 mm.

Remarks.—This shell is referred to *Strepsidura* largely because of the general resemblance it bears to *Strepsidura ? mediavia* Harris[51] from Alabama. It is a much larger and heavier shell, but is closer to that species than any that has been described.

Unfortunately, the single shell from Soldado is so fragmentary that all the

[51] Bull. Am. Pal., Vol. I, pp. 205–206, pl. 8, figs. 16, a, 17, 1896.

columellar characters are lost. But the anterior canal appears not to have been sharply reflexed. In this as well as in the general form of the spire it resembles *mediavia.*

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene.

Genus **MELONGENA** Schumacher, 1817.

Melongena melongena Linnæus. Plate XI, Figure 5.

Pyrula melongena Linnæus, Syst. Nat., Ed. 12, 1220.
Pyrula melongena Guppy, Geol. Mag., p. 438, 1874 (*pars*).
Melongena melongena Tryon, Man. Conch., vol. III, p. 107, 1881.

Remarks.—This species does not extend below the Pliocene. In the Oligocene of Jamaica and Haiti and in the Manzanilla beds of Trinidad there is a closely related form, *Melongena consors* Sowerby. Gabb in 1873 regarded the latter species as identical with the Pliocene and recent *M. melongena;* but Dr. Guppy in 1876 questioned this,—and Dr. Dall in 1890 after examining the Santo Domingan shells decided they were specifically distinct.

As is characteristic with the genus, *M. melongena* varies greatly in the development of spines. It is found living throughout the West Indies. Some specimens are occasionally entirely smooth and devoid of spines; but according to Tryon there are usually on adult shells one to three rows of spines on the upper part of the body whorl and an additional row half way to the base of the whorl. This is the case with the shell figured from the Quaternary of Venezuela. This specimen shows three rows of spines on the shoulder and one row near the base of the shell.

This species evidently flourished in the fauna of the raised beach near Guanoco, where it is well developed and abundant. It also occurs in the Pliocene and recent faunas of Trinidad. A large specimen measures 90 mm. in length and 68 in breadth.

Locality.—The Barranca, along the Guanoco and La Brea railroad about a mile northeast of Guanoco, Venezuela.

Geological horizon.—The fossils occur in a raised beach of Quaternary age.

Genus **PSEUDOLIVA** Swainson, 1840.

Pseudoliva bocaserpentis new species. Plate XI, Figure 6.

Description.—On first examination, this shell appeared as a varietal form of *P. scalina* Heilprin[52] from the Midway Eocene of Alabama. But further study makes it appear rather as a distinct species. The single specimen obtained from Soldado Rock is unfortunately fragmentary but shows very well marked characters. These place it in an intermediate position between *Pseudoliva scalina* and *P. ostrarupis* Harris[53] from the Midway of Texas. The Soldado shell resembles *scalina* in having longitudinal plications on the body whorl, but these,

[52] Proc. Acad. Nat. Sci. Phila., p. 371, pl. 20, fig. 12, 1880.
[53] Proc. Acad. Nat. Sci. Phila., p. 75, pl. 8, figs. 3a, 1895.

instead of extending to the sulcus as in that species, become obsolete a short distance below the shoulder; nor has the Soldado shell the five impressed spiral lines revolving round the basal part of the body whorl below the sulcus,—only one rather faint line is present. A more striking difference between these forms is the breadth of the shoulder of the last volution in the Saldado shell, and the very strong wrinkles which pass diagonally across it and over the penultimate whorl. These wrinkles recall at once those of *P. ostrarupis*, but in that species they do not extend over the preceding whorl; the Soldado shell also resembles *P. ostrarupis* in the general form of the lower part of the body whorl which is broader and less pointed than in *scalina*.

As the Soldado shell is thus about equally allied to both *scalina* and *ostrarupis* of the Gulf Coast Midway, it would be perplexing to determine which affinity is closer, and rather than place it as a variety of either, it is described as an independent, but intermediate species.

Remarks.—It is an interesting fact showing the close resemblances between the Soldado Rock, Bed No. 2 fauna, and that of the southern United States that a specimen of *scalina* from the Lignitic beds at Nanafalia, Alabama, in the Cornell University Paleontological Museum (No. 12110) shows the same tendency of the longitudinal plications to become obsolete not far below the shoulder of the last volution. The diameter of the Soldado *Pseudoliva* is about 15 mm.

Dr. C. A. White in 1887 described from the Rio Maria Farinha beds, State of Pernambuco, Brazil, *Harpa dechordata*,[54] which Professor Harris in 1896 placed with a question under the synonymy of *Pseudoliva scalina*.[55] This Brazilian form is unlike the Soldado shell, but it is very like *Pseudoliva scalina* which it almost certainly is.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to that of Alabama and of Rio Maria Farinha beds, State of Pernambuco, Brazil.

Genus **COLUMBELLA** Lamarck, 1799.

Columbella labreana new species. Plate XII, Figure 1.

Description.—Shell very small, biconic, very convex; number of whorls five, the first being nuclear, very small and smooth (lacking in the specimen illustrated); subsequent whorls ornamented by flattened spiral threads most marked towards the base of the shell and becoming obsolete above the middle of the last volution; longitudinal sculpture of regular, narrow, close-set, rounded ribs (eighteen on the last whorl), not extending quite to the suture, being interrupted above by a narrow, subsutural band; outer lip somewhat thickened, internally dentate on the margin and lirate within, columella very finely and closely plicate.

Height of shell 5, greatest width 2 mm.

Remarks.—This little shell seems to be akin to Sowerby's *C. haitensis*, as far as one can judge by a bare description.

[54] Arch. do Museu Nac. do Rio de Janeiro, VII, pp. 136–137, pl. XIII, figs. 7, 8.
[55] Bull. Am. Pal., I, p. 214.

It is very like specimens of the recent *Columbella* (*Anachis*) *obesa* C. B. Adams from the shores of the Gulf of Mexico, but is larger and stronger than the latter shell, of which it would seem to have been an ancestral form.

Locality.—Along the shore 700 feet east of the pier at Brighton, Trinidad, in an impure asphalt.

Geological horizon.—Upper Oligocene. Approximately equivalent to the Chipolan stage of Florida.

Columbella asphaltoda new species. Plate XII, Figure 2.

Description.—Shell of moderate size, broadly fusiform, with an acute spire; number of volutions seven, of these the first two are nuclear and nearly or quite smooth; subsequent whorls ornamented by regular, rather close-set, narrow, sharply defined, longitudinal ribs (sixteen on the last whorl), extending from suture to suture, and on the last whorl beyond the periphery, becoming obsolete on the base; spiral sculpture of rather strong flattened threads, most marked on the base and interspaces between the ribs, which they do not cross except at the basal portion of the shell; aperture elliptical, rather short and broad, inner lip not plicate, with a mere wash of callus, outer lip very slightly thickened with only three or four faint liræ within.

Height of shell 16, greatest width 7 mm.

Remarks.—Of the Columbellas described from the Antillean beds this shell in its type of sculpture is nearest to *C. venusta* Sowerby from Santo Domingo and Cumana, Venezuela. The latter shell is however a more slender and elongated form with a strongly lirate outer lip and a plicated columella.

This shell and *C. labreana* are the first Columbellas yet found in beds older than Pliocene on Trinidad.

Locality.—On the shore 700 feet east of the Brighton pier, Trinidad, in an impure asphalt.

Geological horizon.—Upper Oligocene, about equivalent to the Florida Chipolan.

Genus **TROPHON** Montfort, 1810.

Trophon progne ? White. Plate XI, Figures 7, 8.

Trophon progne White, Arch. do Museu Nac. do Rio de Janeiro, vol. VII, pp. 139–140, pl. XI, fig. 14, 1887.

White's original description.—"Shell short, fusiform; spire much shorter than the last volution, including the beak, volutions six or more in number, convex, angular at their periphery; the last volution proportionally large; the distal side of the volutions of the spire broader than the proximal side, flattened and sloping outward and forward from the suture; the peripheral portion of the volutions bearing prominent nodes or short varices which, on the last volution, become subspinous. The surface of the distal side of the volution is marked only by lines of growth, but the proximal side is marked by coarse revolving raised lines, and these are crossed by distinct lines of growth; aperture large; columella strong; canal short; beak reflexed.

"Length 26 mm.; breadth of the last volution 18 mm."

Type locality. Rio Maria Farinha beds, State of Pernambuco, Brazil.

Remarks.—Two fragments of a *Trophon*, probably of this species, were found at Soldado, but their condition is such that a positive identification is not possible. They may have constituted a variety of Dr. White's species, for the sculpture of transverse raised lines is closer and less regular, and one shell evidently was considerably larger than the Brazilian type.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Genus **PURPURA** Bruguière, 1789.

Purpura sp. indet. Plate XII, Figure 4.

A fragment of an interior mould of a species of *Purpura* was found south of Pitch Lake.

In the general form and presence of two rows of nodules on the periphery of the body whorl it recalls young shells of the recent species *Purpura hæmastoma* Linn. of which it is apparently an ancestral form.

No positive identification is possible because of the very imperfect condition of the fossil.

Locality.—Southern main road just south of Pitch Lake, Brighton, Trinidad, in a yellowish-brown, ferruginous marl.

Geological horizon.—Upper Oligocene.

Cymia woodii Gabb. Plate XI, Figures 9, 10.

Fasciolaria Woodii Gabb, Jour. Acad. Nat. Sci. Phila., 2d ser., IV, p. 375, pl. 67, fig. 7, 1860; Conrad, Proc. Acad. Nat. Sci. Phila., XIV, p. 561, 1863.
Fasciolina Woodii Conrad, Am. Jour. Conch., III, p. 186, 1867.
Cuma tectum Gabb, Trans. Am. Phil. Soc., n. s., XV, p. 214, 1873.
Not *Cuma tectum* of Kiener (*Pyrula tectum*), nor of Wood (*Buccinum tectum*), nor of Reeve (*Turbinella tectum*).
Cymia Woodii Dall, Trans. Wagner Inst. Sci., III, p. 155, 1890.
Fasciolaria Woodii Whitfield, Monograph U. S. Geol. Surv., No. XXIV, pp. 98–99, figs. 7, 8, 1894. (Gabb's type refigured.)
Purpura (*Cuma*) *Woodii* Guppy, Canadian Inst. Trans., p. 390, 1909.

Gabb's original description.—"Fusiform; whorls four or five, flattened so as to make the sides of the spire nearly straight; outer lip plain; columella with one prominent fold; canal moderate, umbilicus nearly obsolete; surface marked by numerous revolving ribs which exhibit a slight tendency to alternate in size.

"Dimensions.—Length 1.3 in., width of body whorl .8."

Locality.—Miocene marl, near Shiloh, Cumberland Co., N. J.

Remarks.—The *Cymia* from Trinidad is very like specimens of *Cymia tectum* Wood, now living on the west coast. On comparing the fossil with shells in the Newcomb collection that were found living on the coast of Ecuador, the spires are almost exactly alike, but there is a difference in the contour and proportional lengths of the body whorls. The most striking difference, however, is that the

Trinidad shell has two rows of tubercles on the last volution. No doubt the Trinidad shell is the ancestral form of the living *C. tectum*.

The history of the description of the fossil shell is interesting. In 1873 Gabb found in the "Miocene" of Santo Domingo a large series of shells, similar to the specimens from Trinidad now under discussion, which showed a remarkable tendency to variations. He referred them to *Cuma tectum* Wood and remarked:[56] "This well known Panama shell is very common in the Santo Domingo beds, and goes through an astonishing series of variations. I have it with a rounded body, without a tubercle, and varying from that to a broadly angulated and umbilicated form, with six immense tubercles on the angle. Between these, and other extremes, I fortunately possess complete series connecting them without question."

But in 1860[57] Gabb had described *Fasciolaria woodii* from the "Miocene" marl near Shiloh, New Jersey. This is a nearly smooth form, externally not unlike a young *Fasciolaria*. Indeed, with only the two extremes to compare, one could not believe that the nearly smooth New Jersey form and the strongly tuberculated southern form are the same species. However, Dr. Dall on examining the type shell of Gabb's *Fasciolaria woodii* from New Jersey found that it was a typical *Cymia*. Later, on studying Gabb's series of "*Cuma tectum*" from Santo Domingo, he found that the smooth varieties grade perfectly into the New Jersey form. Hence the species called by Gabb *Fasciolaria woodii* and those referred by him to "*Cuma tectum*" from Santo Domingo are identical specifically. In Dr. Dall's opinion, however, the "*Cuma tectum*" of Gabb from the Santo Domingo beds is not the same species as the *Cuma tectum* of Wood and of Kiener, a recent species common in the Panama region and found along the west coast of Central America as far south as Ecuador (Newcomb). Dr. Dall says:[58] "On examining the unique type of Gabb's *Fasciolaria woodii* I saw at once that it is a typical *Cymia;* but my astonishment was great when, on looking over the large series of the Miocene fossil from Santo Domingo which Gabb had referred to *Cuma tectum*, I found that the two could not be separated specifically, and that neither should be referred to *C. tectum*.

"The *C. woodii* is a very variable shell with or without tubercles and peripheral carina, and varying much as some Purpuras do. The fine series at Philadelphia shows this well, and among the smoother varieties the exact duplicate of the New Jersey fossil can easily be found."

Dr. Dall[59] calls attention to the fact that Conrad's *Tritonopsis subalveatum*[60] may be this species, as it is a true *Cymia*. It was found at the base of the Vicksburg beds (Lower Oligocene) of Mississippi, but no positive specific identification of it has been made.

[56] Trans. Am. Phil. Soc., XV, p. 214, 1873.
[57] Jour. Acad. Nat. Sci. Phila., 2d ser., IV, p. 375, pl. 67, fig. 7, 1860.
[58] Trans. Wagner Inst. of Sci., III, p. 155.
[59] Trans. Wagner Inst. Sci., vol. III, p. 155.
[60] Jour. Acad. Nat. Sci. Phila., 2nd ser., II, p. 41, pl. 1, figs. 2, 8, 1850 = *Triton subalveatum, op. cit.*, I, p. 207, 1849.

Locality.—Along the shore 700 feet east of the Brighton pier, Trinidad Island, in an impure asphalt.

Geological horizon.—Judging from the indications reviewed under the genus *Cymia*, and from the distribution of this series, the writer believes the horizon in which the shell was found to be approximately equivalent to the Chipola epoch (Upper Oligocene) of Florida.

Genus **MUREX** Linnæus, 1758.

Murex cf. domingensis Sowerby. Plate XII, Figure 3.

Cf. Murex domingensis Moore, Quart. Jour. Geol. Soc. London, vol. VI, p. 49, pl. X, fig. 5, 1850.

A fragment of an interior cast of a *Murex* was found in the ferruginous marl south of Pitch Lake.

In its general form it suggests *Murex domingensis* which is found in Jamaica, Haiti, and Cumana, Venezuela. It may perhaps be a cast of that species, but no definite determination is possible because of the fragmentary and imperfect condition of the fossil.

Locality.—Southern main road, just south of Pitch Lake, Brighton, Trinidad, in a yellowish-brown, ferruginous bed.

Geological horizon.—Upper Oligocene.

Genus **CASSIS** (Klein, 1753) Lamarck, 1799.

Cassis (Phalium) guppyana new species. Plate XII, Figures 5, 6.

Description.—Young specimens small, short and very rounded so as to appear almost globular; whorls about four or five; spiral sculpture of (1) fine revolving striæ which are most strongly marked on the lower part of the last volution, where, in well preserved shells, they alternate with finer raised lines, and (2) of three carinæ, one on the shoulder and two below; the humeral carina in all the specimens bears short, spinous nodules, while the two below either are nearly smooth (as in the figured shell) or are decorated with smaller nodules; characters of the columella and aperture concealed by the indurated matrix.

Height of fragment figured 13, greatest diameter 9 mm.

A fragment of part of the outer lip of a *Cassis* was found in the same bed as the young shells described above. The strong probabilities are that this is a fragment of an adult individual of the same species. It shows six well marked plications which, judging from the curve of the fragment, would be situated near the central part of the outer lip.

Remarks.—The Soldado *Cassis* is very closely allied to *Cassis* (*Phalium*) *brevidentatum* (Conrad) Aldrich.[61] This has typically a single row of nodules on the shoulder, although Professor Harris has figured[62] a variety from the Alabama Lignitic with the two lower carinæ nodular on the back of the shell but not in front. That variety, however, differs from the Soldado shell in being

[61] *Cassidaria brevidentatum* Aldrich, Jour. Cinn. Soc. Nat. Hist., p. 152, pl. 3, fig. 20, 1885.

[62] Proc. Acad. Nat. Sci. Phila., p. 479, pl. 22, fig. 10, 1896.

broadly and deeply sulcate between the carinæ and the plications on the outer lip are obsolete.

The history of *C. brevidentata*, is rather confused. It was first mentioned by Conrad[63] from the Claiborne sands, but was not figured for many years. In 1890, a shell specifically the same was described by Dr. Dall[64] as *C. globosum* from the Oligocene of Chipola, Florida, and was figured in 1892.[65] Dr. Dall's figure 11, which is of a young Chipolan specimen, is very like the young Soldado form. Yet, although the general type is the same, the Soldado shell shows minor differences, as greater breadth of shoulder, more spinous and less rib-like nodules and a less highly sculptured spire. Moreover, if we may assume the fragment of the outer lip of the adult *Cassis* to be of the same species as the young shells, it settles the question rather definitely. It is strongly plicate even in the central part, while *brevidentatum* is described by Mr. Aldrich as smooth in the center; and Dr. Dall says that the outer lip of *globosum* is feebly denticulate.

For the above reasons the writer is disposed to regard the Soldado shell as a different species but closely allied to *C. brevidentatum* (= *globosum*).

The Soldado form is named in honor of Dr. R. J. Lechmere Guppy, of Port of Spain, Trinidad.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria, near the Serpent's Mouth.

Geological horizon.—Lignitic Eocene.

Cassis togata White.

Strombus togatus White, Arch. do Museu Nac. do Rio de Janeiro, vol. VII, pp. 170–171, pl. XV, figs. 13, 16, 1887.

White's original description.—"Shell comparatively short; spire equal in length to about one-quarter of the full length of the shell; volutions five or more in number, the last one large; those of the spire convex; their distal side closely appressed against the preceding volution; each volution bearing from eight to ten narrow, abruptly raised, longitudinal varices, which end at the small appressed fold at the distal border of the volutions of the spire, but they reach the suture upon the proximal border. These varices on the last volution extend forward a little more than one-half its breadth, where they become obsolete. The surface upon the anterior portion of the last volution is marked by coarse, revolving, raised lines; and sharp, close-set lines of growth are visible on well preserved surfaces; aperture moderately large, ending in a short, slightly flexed canal at the front, and at the maturity of the shell the outer lip became expanded both laterally and posteriorly, its margin being everted and a little thickened, rounded at its postero-lateral portion, and bearing a shallow notch near the anterior portion.

"Length 29 mm., breadth of the last volution 16 mm."

Locality.—Maria Farinha beds, State of Pernambuco.

[63] Jour. Acad. Nat. Sci. Phila., 1st ser., vol. VII, p. 146, 1834.
[64] Trans. Wagner Inst. Sci., vol. III, pp. 161–162.
[65] *Ibid.*, p. 262, pl. 20, figs. 6, 11.

Cassis togatus var. soldadensis new variety. Plate XII, Figure 7.

Remarks.—Two shells were collected by Mr. Veatch from Bed No. 2, Soldado Rock, which are very closely related to *Cassis togatus* White from the Maria Farinha beds, Brazil.

Dr. White's description and his figure 13 tally so well in the main with the Soldado shell that the differences between these forms seem varietal only.

Description.—The Soldado shells can be distinguished from those of Maria Farinha by their sharper varices; also in well preserved specimens, by the fine and beautiful cancellation of the entire surface of the body whorl due to the intersection of close, sharp transverse striæ with more delicate lines of growth.

This cancellation is slightly indicated in White's figure 15, but it is much sharper and more regular on the Soldado shell.

When complete the shells from Soldado would not have measured more than 23 or 24 mm. in length, while those from Brazil reached nearly 30 mm.

In general the Soldado variety was a somewhat smaller and more elegantly formed and sculptured shell than the Brazilian type. This species has not been found in the Eocene of our Southern States.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Genus **CYPRÆA** Linnæus, 1758.

Cypraea bartlettiana new species. Plate XI, Figures 11, 12, 13.

Description.—Shell small, solid, broadly pyriform, very globose; surface unsculptured, wholly smooth except for fine, transverse lines of growth; spire entirely enrolled and concealed, very slightly sunken; aperture rather narrow, widening towards the base; inner lip with about twelve fine plications decreasing in size from the base upwards, plications on the outer lip concealed by the indurated matrix; columella pinched at the base into a very sharp ridge.

Height 18, width 14, thickness 11 mm.

Remarks.—This and the succeeding species are the only Cypræas that have ever been described[66] from the Midway Eocene. A single species *C. smithii* has been described by Mr. Aldrich from the Lignitic of Alabama.[67] The latter shell is of somewhat the same general type as *C. bartlettiana*, and has the same sharp columellar ridge, but the form of the shell is flattened instead of globular.

In 1887 Dr. White described a peculiar Cypræa-like fossil from Rio Piabas, State of Para, Brazil, as *Cyprœactœon pennæ*, new genus and species.[68] This has a very deeply sunken spire, and bears no resemblance to the Soldado shell.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

[66] Professor Harris (Bull. Am. Pal., vol. I, p. 217, 1896) mentions finding two Cypræas in the Midway of the Gulf States, one smooth, the other reticulated, but neither was sufficiently well preserved to describe or figure.

[67] Geol. Surv. Ala., Bull. 1, p. 33, pl. 5, fig. 3, 1886.

[68] Arch. do Museu Nac. do Rio de Janeiro, VII, p. 178, pl. IX, figs. 1–5.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Named in honor of Mr. F. R. Bartlett, of Easton, Maryland, who aided Mr. Veatch in collecting fossils from wave-swept Soldado.

Cypræa vaughani new species. Plate XI, Figures 14, 15.

Description.—Shell small, pyriform, tapering to a pointed base, inflated; surface smooth except for faint lines of growth, which are most apparent on the earlier whorls; spire distinct, acute, showing two small volutions, with a clearly defined suture; aperture rather wide, but so filled with the indurated matrix that all plications are concealed; outer lip much thickened, inner lip with a rather fine callus.

Height of shell 24, greatest width 17, thickness 14 mm.

Remarks.—This peculiar *Cypræa* is wholly unlike anything described from the lower Eocene horizons.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene.

Named in honor of Mr. T. W. Vaughan, Washington, D. C., of the United States Geological Survey.

Genus **ROSTELLARIA** Lamarck, 1799.

Subgenus **Calyptraphorus** Conrad, 1857.

Calyptraphorus velatus Conrad var. **chelonitis** White.

Calyptraphorus ? chelonitis White, Arch do Museu Nac. do Rio de Janeiro, vol. VII, pp. 174–175, pl. XI, figs. 17, 18, 19, 1887.

Dr. White in 1887 described a *Calyptraphorus* from Rio Maria Farinha beds, Province of Pernambuco, Brazil, as *Calyptraphorus ? chelonitis.* His description was as follows: "Shell small, subfusiform; the side upon which the aperture opens at maturity is flattened by a large accumulation of callus, by which all trace of the division of the spire into volutions is obliterated upon that side and almost wholly upon the opposite side also. Upon the latter side the accumulation is more irregular, apparently leaving only one spot at the middle, upon which no callus was deposited when the shell reached maturity. The aperture is comparatively small, oblong, ending anteriorly in a minute channel which is excavated out of a long slender beak, which is straight and in line with the axis of the shell; outer lip a little thickened and reflexed, truncated at both the posterior and anterior ends; the outer margin gently convex and bearing at its anterior end a small obtuse projection."

In all respects except the very last, namely, the *obtuse* projection of the labrum—Dr. White's description answers to the Soldado forms. This character, however, is important, and brings the Brazilian shell closer to the type of *velatus* than those from Soldado. But as it is constantly smaller, and differs in some other respects from *velatus*, the writer would suggest that Dr. White's specific name *chelonitis* should be used as a varietal name to distinguish the Brazilian form of the species *velatus*.

Locality.—Rio Maria Farinha beds, State of Pernambuco, Brazil.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the No. 2 bed of Soldado Rock, Gulf of Paria.

Calyptraphorus velatus Conrad **var. compressus** Aldrich. Plate XII, Figures 8, 9, 10.

Anchura White, U. S. Geol. Surv., Bull. No. 4, p. 17, 1884.
Rostellaria velata Aldrich, Geol. Surv. Alabama, Bull. No. 1, p. 59, 1886.
Rostellaria Smith and Johnson, U. S. Geol. Surv., Bull. No. 43, p. 66, 1887.
Calyptraphorus velatus Harris, Geol. Surv. Arkansas, vol. II, p. 46, 1892.
Rostellaria (*C.*) *velatus* var. *compressa* Aldrich, Geol. Surv. Alabama, p. 244, pl. 12, figs. 2, 2a, 2b, 1894.
Calyptraphorus velatus var. *compressa* Harris, Bull. Amer. Paleont., vol. I, p. 218, pl. 10, figs. 7a, b, 8, 1896.

Aldrich's original description of the variety.—"This form is intermediate between *R. trinodifera* Con. and *R. velata* Con. The adult has the enamel on the front part as in *R. trinodifera*, but on the opposite side the line of demarkation of the enamel comes down only to the (body) whorl. The specimens are also much smaller than the normal adult. A similar form that cannot be separated from this variety is common in the Matthew's Landing group, but is nearly twice as large, and more rotund than those figured. The figures given are somewhat larger than the type."

Remarks.—Professor Harris has found this variety in the Midway of Texas, Arkansas, Tennessee, Mississippi, Alabama and Georgia. He says[69] "The smaller type of this variety is common in the lower and medial Midway beds. It is one of the first to appear above the Eocene-Cretaceous contact line. The larger specimens differ from the *Calyptraphorus velatus* from the Claiborne sand mainly by the pointed exterior-posterior termination of the labrum; in *velatus* this portion of the labrum is rounded, as shown by figure 5, Plate 15, of Conrad's *Fossil Shells*, etc., 1835."

In view of the wide distribution of this variety in the Midway horizons of the southern states of North America—it is exceedingly interesting to find that it is a common shell at Soldado Rock, Bed No. 2. It occurs in it with masses of *Cucullæa harttii, Turritella mortoni, T. nerinexa, Venericardia planicosta* and a mass of moulds and fragments of other species forming a veritable shell breccia like the modern *coquina* rock.

One specimen of the *Calyptraphorus* fortunately shows the sharply pointed posterior termination of the labrum which differentiates this variety. The shells are the small early Midway type, the fragments measuring about 25 by 14 mm.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

[69] Bull. Am. Pal., I, p. 218, 1896.

Subgenus **Rimella** Agassiz.

Rimella fowleriana new species. Plate XII, Figure 11.

Description.—Shell of moderate size, rather broadly fusiform; number of whorls known five; sculpture on last volution consisting only of about fifteen delicate, spiral striæ revolving around the basal half of the whorl which is elsewhere entirely smooth; sculpture on penultimate whorl consisting of one strong medial spiral thread and a few rather irregular, more or less obsolete, longitudinal riblets, better developed on the earlier half of the whorl; sculpture on third whorl consisting also of one medial revolving spiral and a number of close-set longitudinal riblets or plications; the latter also form the ornamentation of the fourth and fifth volutions; each whorl has one or more rather inconspicuous varices.

Length of incomplete shell 21, greatest width 10 mm.

Remarks.—This is the first *Rimella* found in the Lower Eocene. None has before been discovered in either the Midway or Lignitic horizons of southeastern North America or northeastern South America.

The writer takes great pleasure in naming this shell in honor of Mr. William Fowler, of Guanoco, Venezuela, whose many kindnesses did so much to render pleasant her visit to Venezuela.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Rimella knappiana new species. Plate XII, Figures 12, 13.

Description.—Shell of moderate size, slender, subfusiform, with a high, very acute and tapering spire; whorls nine or ten; spiral sculpture, on very well preserved specimens, of microscopic striæ which are exceedingly fine all over the shell, and of about ten strong spiral lines at the base; longitudinal sculpture of sharp-edged, close-set plications which are present on all the whorls (although in some cases the whorls appear perfectly smooth, which is because the entire outer surface has been removed by erosion); this handsome and even plication of the whorls, extending over the last volution as well, immediately differentiates this species from *R. fowleriana;* characters of base of shell and outer lip shown by the second figure; the posterior canal in adult shells forms a sharply-ridged gutter extending almost to the tip of the spire to which it is adherent.

Height of shell 22, greatest width 8 mm.

Remarks.—This shell is one of the most abundant species in the Soldado Lignitic fauna.

The writer takes great pleasure in naming it in honor of Mr. I. N. Knapp, of Morgan City, Louisiana, whose kind gift of deep well fossils has done so much to further our knowledge of the depth and extent of the Quaternary strata of the Gulf States.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Genus **ROSTELLARIA** Lamarck, 1799.

Subgenus **Veatchia** new subgenus.

Description.—A single fragment of a shell was found at Soldado Rock, Bed No. 2, which in general form resembles the subgenus *Orthaulax* Gabb. It differs, however, from the latter in a very curious characteristic which marks it as altogether *sui generis*.

This differentiating character is the curving into loops of the posterior canal, which is adherent to the upper portion of the body whorl. In this respect the shell approaches the subgenus *Calyptraphorus* Conrad, in which the posterior canal makes one semicircular curve over the dorsal side of the body whorl.

Thus the subgenus *Veatchia* lies in an intermediate position between the subgenera *Orthaulax* and *Calyptraphorus*.

The writer dedicates this new subgenus to Mr. Arthur C. Veatch, of Washington, D. C., in pleasant memory of our geological work in Venezuela.

Veatchia carolinæ new species. Plate XII, Figures 14, 15, 16.

Description.—Shell when complete rather large, thick and heavy, spire short, obtusely pointed, whorls completely concealed, all the upper portion of the shell being self-enrolled by the posterior prolongation of the last volution, which is wrapped about the spire like a mantle; characters of the columella and anterior canal not known; posterior canal described above under the subgenus.

Height of fragment 27, greatest width 28, greatest thickness 21 mm.

This species is named in honor of Mrs. Veatch.

It is the type of the subgenus.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and that of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Genus **CERITHIUM** Adanson, 1757.

Cerithium harrisii new species. Plate XII, Figure 18.

Description.—Shell rather small, solid, strong; conic, with an acute spire; nuclear whorls two, smooth; subsequent whorls four, ornamented on the penultimate volution by three spiral rows of bead-like nodules, with intervening faint, spiral threads; last volution also with three prominent rows of beads alternating with spiral threads, but with a similar, though more or less obsolete, ornamentation over the basal part of the whorl; penultimate whorl with a varix which angulates the outline of the shell; body whorl with two rather strong varices.

Height of shell 15, greatest width 5 mm.

Remarks.—Dr. Guppy cites *C. uniseriale* Sow. and *C. plebium* Sow. from Trinidad, to neither of which this shell bears any except a generic resemblance.

Gabb briefly described about ten species of *Cerithium* from Haiti. These have never been figured, and without the types it is almost hopeless to attempt to recognize them.

Locality.—Along the shore 700 feet east of the pier at Brighton, Trinidad, in an impure asphalt.

Geological horizon.—Upper Oligocene, about equivalent to the Chipolan stage of Florida.

Cerithium isabellæ new species. Plate XII, Figure 19.

Description.—Shell short and broad, conic, with a rather obtuse spire; whorls about five, of which the penultimate is ornamented with three spiral rows of bead-like nodules, with sets of three (less frequently two) revolving spiral threads intervening between the rows of beads; last volution also with three main rows of nodules with intervening sets of spiral threads, this ornamentation being continued more or less obsoletely towards the base of the shell; varices apparently not developed (shell partially concealed by the matrix).

Height 16, greatest width 8 mm.

Remarks.—This shell resembles in form and sculpture *C. webbi* Harris from the Lower Claiborne Eocene of Texas. It is an interesting fact that three species of *Cerithium* described in this report (*C. soldadense*, *C. harrisii*, and *C. isabellæ*), should resemble the Texan shell, and be quite unlike any figured from Florida.

This species can be distinguished from the closely related form, *C. harrisii*, by its much broader proportions, greater number of spiral threads, and absence of varices.

Locality.—Along the shore 700 feet east of the pier at Brighton, Trinidad, in an impure asphalt.

Geological horizon.—Oligocene. About equivalent to the Chipolan stage of Florida.

Cerithium soldadense new species. Plate XII, Figure 20.

Description.—Shell small, convex, number of whorls not known; transverse sculpture of narrow, curving, rather irregular, plications, present chiefly on the penultimate volution; spiral sculpture of revolving beaded threads alternating with finer beaded lines; on the body whorl there are two or three of the coarser beaded threads, and then a fine row of beads just below the suture.

Diameter of last whorl 4 mm.

Remarks.—This species has no resemblance to any described from the Midway of the southern States, nor has it been found in the Maria Farinha beds of Brazil. Its closest affinity in general form and type of sculpture is *C. webbi* Harris[70] from the Lower Claiborne Eocene of Texas.

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, in the Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and that of the Rio Maria Farinha Beds, State of Pernambuco, Brazil.

[70] Proc. Acad. Nat. Sci. Phila., p. 79, pl. 9, fig. 3, 1895.

Cerithium tinkeri new species. Plate XII, Figure 17.

Description.—Shell, judging from the gutta-percha cast made from its impression, rather broad, solid and strong, number of whorls known seven; longitudinal sculpture of numerous narrow riblets which are interrupted by four or five impressed spiral lines, the one immediately below the suture constituting a narrow groove.

Height approximately 25 mm.

This species is named in honor of Dr. Tinker, of Cornell University.

Locality.—Southern main road just south of Pitch Lake, Brighton, Trinidad, in a ferruginous marl.

Geological horizon.—Upper Oligocene.

Genus **CERITHIOPSIS** Forbes and Hanley, 1849.

Cerithiopsis veatchiana new species. Plate XII, Figure 21.

Description.—Shell small and slender, tapering to a high, acute spire; whorls fourteen, of which the three nuclear are smooth, the fourth from the apex ornamented only with revolving striæ; subsequent volutions with (*a*) four or five rather strong spiral threads; and (*b*) numerous narrow, oblique longitudinal plications (about twenty on the last volution); these at their intersections with the spiral threads become slightly nodular; columella showing two rather faint plications.

Height of shell 8, greatest width 3 mm.

Remarks.—This very delicate little shell is unlike any described from the Lower Eocene.

It is dedicated to Mr. Arthur C. Veatch, of Washington, D. C., by whom it was found.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Genus **TURRITELLA** Lamarck, 1799.

Turritella humerosa Conrad.

T. humerosa Conrad, Trans. Geol. Soc. Penn., vol. 1, p. 340, pl. 13, fig. 3, 1835.
T. humerosa H. C. Lea, Proc. Acad. Nat. Sci. Phila., vol. IV, p. 107, 1848.
T. humerosa Conrad, Amer. Jour. Conch., vol. I, p. 32, 1865.
T. eurynome Whitf., Amer. Jour. Conch., vol. I, p. 266, 1865.
T. multilira Whitf., *ibid.*, p. 266.
T. bellifera Ald., Geol. Surv. Ala., Bull. No. 1, p. 34, pl. 1, fig. 13, 1886.
Turritella elicita White, Arch. do Museu Nac. do Rio de Janeiro, VII, pp. 162–163, pl. XVIII, figs. 6, 7, 1887. Not of Stoliczka.
T. cathedralis var. *bellifera* De Greg., Mon. Faun. Eoc. Ala., p. 127, pl. 11, figs. 17, 18, 1890.
T. humerosa Harris, Amer. Jour. Sci., ser. III, vol. XLVII, p. 303, 1894.
T. humerosa Clark, Bull. 141, U. S. Geol. Surv., p. 70, pl. XIV, fig. 1, 1896.
T. humerosa Harris, Bull. Amer. Pal., vol. I, pp. 110–111, pl. 11, fig. 11 (typical), 1896; Bull. Amer. Pal., vol. III, p. 75, pl. 10, figs. 5, 6, 7, 1899; Geol. Surv. La., p. 308, pl. 55, fig. 5, 1899.
T. humerosa Clark, W. B., Eocene, Md. Geol. Surv., pp. 148–149, pl. XXVII, figs. 1, 1a, 1901.
T. elicita Arnold in Branner, Bull. Mus. Comp. Zoology, Harvard College, vol. XLIV, 1904.

Conrad's original description.—"Shell turrited, subulate; whorls with fine regular revolving striæ; an obtuse slight elevation on the summit, a shallow groove at the base of each.

"From the Eocene of Piscataway, Maryland."

Remarks.—Dr. C. A. White in 1887[71] described and figured a *Turritella* from the Rio Maria Farinha beds, State of Pernambuco, Brazil, which he identified as *Turritella elicita* Stoliczka, originally described from the Cretaceous rocks of southern India.[72]

Dr. White says: "The Brazilian examples differ from the Indian only in a little greater distinction of the revolving lines which mark the surface; but this may be due to a difference attending the fossilization of the shells; and if not, it is not deemed of specific importance." The Maria Farinha specimens were all fragmentary, but the full length of an adult example was estimated by Dr. White as not far from 150 mm. with a diameter of the last volution of 27 mm. Now the Brazilian shell differs from that from Soldado in the presence in the former of slender revolving raised lines, and in the greater prominence of the rounded ridge at the distal border of each volution near the suture. These characteristics, especially as indicated in Dr. White's fig. 7,[73] ally the shell more closely with typical *T. humerosa* Conrad than with the Soldado variety or with the Indian *Turritella elicita* Stol. Indeed Dr. White's figures are so exactly like typical specimens in the Cornell University Museum of *T. humerosa* from Nanafalia, Alabama, that there can be no question of the identity of the Brazilian and Alabama forms.

This species ranks secondary to *T. mortoni* as a typical lower Eocene shell. Professor Harris has found that although this species is most typically represented in the Lignitic of Alabama, Virginia and Maryland, it occurs very abundantly in nearly all horizons of the Midway, and displays a remarkable variety of forms. It is common in Alabama, Texas and Arkansas.

The true identity of the Maria Farinha *Turritella* is thus not with the Cretaceous species of India, *T. elicita* Stoliczka from the Arrialoor group; but with Conrad's *T. humerosa* from the North American Lower Eocene. The same species was found by Dr. Branner in Ponto das Pedras, State of Pernambuco, Brazil, where the fauna is of the same age as that of Maria Farinha.

Turritella humerosa Conrad var. **elicitatoides** new variety. Plate XII, Figure 22.

Cf. Turritella elicita Stoliczka, Pal. Indica, II, p. 221, pl. XIV, fig. 3, 1868.

Remarks and description.—Several fragments of a *Turritella* resembling *T. humerosa*, were obtained from Soldado Rock, Bed No. 2. These show none or only the very faintest traces of the "fine revolving striæ" characteristic of the typical specimens. In this respect they are like a large variety of this species from Prairie Creek (No. 204 U. S. Nat. Mus.), figured in Professor Harris' Midway stage;[74] but the whorls of that shell are much shorter proportionally than those of the Soldado form. The latter also resembles a rather smooth specimen (not typical) from Nanafalia, Ala.

[71] Arch. do Museu Nac. do Rio de Janeiro, pp. 162–163, pl. XVIII, figs. 6, 7.
[72] Pal. Indica, vol. II, p. 221, pl. XVI, fig. 3, 1868.
[73] *Loc. cit.*
[74] Bull. Amer. Pal., vol. I, pl. 21, fig. 12, 1896.

The Cretaceous shell described by Stoliczka[75] as *Turritella elicita* from the Arrialoor group at Ninnyoor, southern India, is much more closely allied to the Soldado shells than to those of Maria Farinha, Brazil, with which Dr. White identified it, but, judging from the illustration, the Indian *Turritella* was more slender in proportion to its length than the Soldado form.

Stoliczka's original description of *T. elicita* is as follows: "Turr. testa perlonga, valde attenuata anfractibus numerosis, postice late tumescentibus, ad medium paulo excavatis, superioribus spiraliter minute striatis atque liratis, inferioribus lævigatis; striis incrementi minutis, supra medium valde insinuatis; ultimo anfractu ad peripheriam basalem subcarinato; basi paululum producta; apertura subquadrangulari, altiore quam lata."

Both the Indian and the Soldado shell show a marked flattening of the prominent ridge at the distal border of the whorls close to the suture. Judging from the fragments the Soldado adult shells must have been about 140 mm. in length. But as only few and fragmentary specimens have been obtained from the Soldado Midway and from the Indian Cretaceous beds (Ninnyoor, Arrialoor group) exact comparisons cannot be made. At present one can only say that with the exception of its slenderer form the Indian *Turritella* appears to be almost identical with that from Soldado. Whether this resemblance is due to specific descent or merely to parallelism in development is left as an interesting and open question.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria, near the Serpent's Mouth.

Geological horizon.—Midway Eocene. Equivalent to that of the Alabama Midway and of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Turritella nerinexa Harris. Plate XII, Figure 25.

Turritella nerinexa Harris, Proc. Acad. Nat. Sci. Phila., p. 82, pl. 9, fig. 9, 1895.
Turritella nerinexa Harris, Bull. Amer. Pal., vol. I, p. 225, pl. 11, fig. 14, 1896.

Harris' original description.—"Size and general form of a fragment (the only known specimen) as indicated by the figure; number of whorls unknown, ornamented by (1) fine, even spiral striæ, (2) a subsutural row of pustules or crenules, and (3) a slightly raised or faint ridge at the base of each whorl becoming obsolete in the lower whorls, but increasing in strength above so as to nearly equal in size the subsutural line of crenules.

"*Locality.*—Black Bluff, Brazos River, extreme northern limit of Milam Co., Milam Bluff of Penrose's report.

"*Geological horizon.*—Midway Eocene.

"*Type.*—Texas State Museum."

Remarks.—It is most interesting to find at Soldado this *Turritella* which is as beautiful as it is rare. After finding the single specimen in Texas, Professor Harris later found others, also in the Midway Eocene, in Alabama, and in Arkansas.

The shells from Soldado answer the description of the type perfectly. One

[75] Pal. Indica, Geol. Surv. India, vol. II, p. 221, pl. XIV, fig. 3, 1868.

rather large specimen even shows the typical characteristic of the ridge above the row of beadings becoming obsolete on the lower whorls.

Height of shell figured 20, greatest diameter 9 mm. Greatest diameter of largest specimen found at Soldado 12 mm.

In 1887 Dr. White described a shell with very similar form and ornamentation from the Maria Farinha beds, Province of Pernambuco, Brazil, under the name of *Nerinea buarquiana*.[76]

As Professor Harris has already pointed out,[77] this species has much in common with *T. nerinexa*.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Basal (Midway) Eocene. Equivalent to the Midway of Alabama and of the Maria Farinha beds, Brazil.

Turritella mortoni Conrad. Plate XII, Figure 23.

Turritella mortoni Conrad, Jour. Acad. Nat. Sci. Phila., vol. VI, pt. 1, p. 221, pl. 10, fig. 2, 1829.
Turritella mortoni Conrad, Fossil Shells of the Tertiary Formation of North America, vol. I, No. 3, p. 40 (96), pl. XV, fig. 11, 1835.
Turritella mortoni H. C. Lea, Proc. Acad. Nat. Sci. Phila., vol. IV, p. 107, 1848.
Turritella mortoni Conrad, Am. Jour. Conch., vol. 1, p. 32, 1865.
Turritella mortoni Heilprin, Proc. Acad. Nat. Sci. Phila., vol. 31, p. 219, 1879.
Turritella sylviana (Hartt) White, C. A., Arch. do Museu Nac. do Rio de Janeiro, vol. VII, pp. 161–162, pl. XVIII, fig. 10, 1887.
Turritella mortoni Smith and Johnson, U. S. Geol. Surv., Bull. 43, pp. 30, 33, 1887.
Turritella mortoni de Gregorio (ex parte), Am., Geol. et Pal., p. 122, pl. 11, fig. 7, 1890.
Turritella mortoni Kennedy, Proc. Acad. Nat. Sci. Phila., vol. 47, p. 147, 1895.
Turritella mortoni Clark, W. B., U. S. Geol. Surv., Bull. No. 141, pp. 40, 44, 45, 46, pl. XIII, figs. 1a–1e, 1896.
Turritella mortoni Harris, Bull. Am. Pal., vol. I, p. 224, 1896; Geol. Surv. Louisiana, p. 229, pl. 52, fig. 9, p. 308, pl. LV, fig. 4, 1899; Bull. Am. Pal., vol. III, pp. 74–75, pl. X, figs. 3, 4, 1899.
Turritella mortoni Clark and Martin, Eocene, Md. Geol. Surv., pp. 147–148, pl. XXVI, figs. 1–5, 1901.

Conrad's original description.—"Shell turreted, conical, thick, with revolving distant, and finer intervening striæ; whorls with an elevated acute carina near the base of each; volutions about 11; the striæ are largest on the elevations of the whorls, which are slightly concave above, and abruptly terminate at the sutures; the lines of growth on the last whorl are strong and much undulated."

Type locality, Maryland.

Remarks.—This *Turritella*, which is a rather common species at Soldado Rock in the Bed No. 2 fauna, is one of the most important and characteristic fossils of the Lower Eocene deposits of the Atlantic and Gulf coasts of the United States. It was first described by Conrad in the Maryland Eocene where it is exceedingly abundant. Dr. Clark[78] shows a photograph of blocks of the Aquia Creek formation made up almost wholly of *T. mortoni*. And great masses of this *Turritella* rock strew the shore at the base of the Aquia Creek and the Potomac Creek bluffs.

Professor Harris[79] remarks that this species occurs in the form of casts in great abundance, large size and of most typical form in a soft layer in the Midway

[76] Arch. do Museu Nac. do Rio de Janeiro, pp. 142–144, pl. XIV, figs. 8, 9, 10, 11.
[77] Bull. Am. Pal., I, p. 225, 1896.
[78] Eocene Md., 1901, pl. III, fig. 2.
[79] Bull. Am. Pal., vol. I, p. 224.

limestone near its base along the Chattahoochee River. Other Midway localities where more or less typical forms have been obtained are in Texas near Kemp, Kaufman County, and in Arkansas near Little Rock. The species also occurs in Tennessee (Middleton), Alabama, and Mississippi; and later Professor Harris adds that the shell presents a great many varietal forms in the Lignitic, and finally merges through the variety *postmortoni* Harris into *T. carinata* of the Claiborne Eocene.

Such being its distribution on the North American continent we will now trace it as far as known in the South American region.

In 1887 Dr. White described *Turritella sylviana* (which is specifically identical with *mortoni*) from the Rio Maria Farinha beds in the State of Pernambuco, Brazil. The figures are very like the Soldado shells both in form and size. It appears as if *T. mortoni* in the far south had become smaller; or else all found so far have been young individuals.

The shells from Soldado Rock, Bed No. 2, are in every respect remarkably close to Conrad's type. They show the sharp carination of the lower part of each whorl which gives a slightly overhanging effect, and the tendency, like the type, to three prominent raised lines near the base of the whorls. They differ only in being smaller.

Length of shell figured approximately 16½ mm., breadth of last volution 6 mm. This is close to the Pernambuco shells which measured about 18 by 6½ mm.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the Maria Farinha beds, Pernambuco, Brazil.

History of the genus.—It is a singular fact that the genus *Turritella*, which began in the Cretaceous, and is so very abundantly represented in the American Tertiaries, in which more than eighty species have been named, should be rare in our seas of to-day. Very few species and individuals are now found, especially on the Atlantic coast of the Americas.

Turritella mortoni Conrad var. Plate XII, Figure 24.

Remarks.—A number of specimens of a *Turritella* were found in the Lignitic fauna of Soldado.

They are probably a varietal form of *T. mortoni* Conrad.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Turritella soldadensis new species. Plate XII, Figure 26.

Description.—Shell small, slender, number of whorls not known; sculpture on each volution consisting of three primary spiral ridges; of which the one directly above the suture is by far the most prominent; and of very faint intermediate spiral threads, only visible with a lens. The lowest basal revolving ridges have a slightly beaded aspect which may be due to erosion.

Height of fragment 12, greatest diameter 6 mm.

Remarks.—This species is allied to *T. clevelandia* Harris[80] from the upper Eocene (Jackson) of Arkansas, which is also ornamented by "three prominent revolving lines and a few subordinate ones," but each volution slopes abruptly both above and below to the suture; making a deep furrow at the sutural lines, which is not the case in the Soldado shell.

Another allied species apparently more closely related is *T. soaresana* (Hartt) White[81] from the Rio Maria Farinha beds of the State of Pernambuco, Brazil. This has the same type of ornamentation, but is also more excavated at the sutures, and was an apparently larger shell than *T. soldadensis.*

Locality.—Bed No. 2, Soldado Rock, near the Serpent's Mouth, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the Rio Maria Farinha beds, State of Pernambuco, Brazil.

Genus **MESALIA** Gray, 1842.

Mesalia pumila Gabb.

Turritella pumila Gabb, Jour. Acad. Nat. Sci. Phila., vol. IV, p. 392, pl. 68, fig. 14, 1860.
Mesalia pumila Harris, Bull. Am. Pal., I, p. 226, pl. 11, fig. 15, 1896.

Gabb's original description.—"Turrited, whorls? (spire is broken) rounded and strongly striate; mouth round; shell very thick; surface marked by three heavy revolving lines on the convexity of the whorl, and one at the base just above the suture, which is small but distinct.

"*Dimensions.*—Length of fragment .5 in., width of body whorl .3 in., diameter of mouth .1 in."

Type locality, Middleton, Tennessee.

Remarks.—During the Lower Eocene period this species developed many varieties. Two of these are in the Soldado Rock, Midway, fauna.

Mesalia pumila var. **allentonensis** Aldrich. Plate XII, Figure 27.

Turritella allentonensis Aldrich, Geol. Surv. Alabama, p. 246, pl. 13, figs. 4a, 6, 1894.
Mesalia pumila var. *allentonensis* Harris, Bull. Am. Pal., I, p. 227, pl. 11, figs. 20, 21, 1896.

Description.—In the Paleontological Museum of Cornell University there are several specimens of this variety from the Midway Eocene near Palmer's Mill, Alabama, which are very close to one of the Soldado shells. The latter has four or five instead of the typical three heavy revolving lines, and is more deeply channeled at the suture than is the type.

Height 34, greatest width 14 mm.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the Rio Maria Farinha beds of Brazil.

Mesalia pumila var. **nettoana** White. Plate XII, Figure 28.

Mesalia nettoana White, Arch. do Museu Nac. do Rio de Janeiro, vol. VII, pp. 164–165, pl. XVIII, figs. 3, 4, 1887.

[80] Rept. Geol. Surv. Arkansas, vol. 2, p. 170, pl. 6, fig. 9, 1894.
[81] Arch. do Museu Nac. do Rio de Janeiro, vol. VII, pp. 160–161, pl. XVIII, figs. 8, 9, 1887.

Remarks.—The majority of the Mesalias from Soldado Rock, Bed No. 2, are somewhat further removed from Gabb's type of *M. pumila* than the variety *allentonensis*. These correspond to Dr. White's description and figures of *M. nettoana* from the Rio Maria Farinha beds in Brazil. The Soldado shells are of practically the same size and are also ornamented with seven, or more rarely eight, raised revolving lines. There is no question of the identity of the Soldado and Brazilian shells.

White's original description.—"Shell moderately elongate; volutions ten or more in number; distinctly and regularly convex, and marked by seven abruptly raised revolving lines or slender ridges of nearly uniform size, and which are separated by interspaces of about equal width with the ridges; the anterior side of the last volution is marked by four or more revolving ridges similar to the others; aperture moderately large, subcircular in outline.

Length about 55 millimeters; breadth of the last volution 22 mm.

Comparison of the Soldado with other forms.—On the front of the specimen figured, the four revolving ridges at the very base of the last volution, mentioned by Dr. White, have apparently been eroded away and the surface seems smooth, but the lines show well on the other side of the shell.

Height of largest fragment from Soldado 42 mm. Diameter of specimen figured 20 mm.

This variety would seem not to have been confined to the tropics; for in the Paleontological Museum of Cornell University there is a specimen (No. 10122) of *Mesalia pumila* Gabb from one mile north of Midway of Alabama of precisely the same form and size as one of these Soldado shells, from which it differs only in having one or two finer raised revolving lines. Otherwise they cannot be distinguished.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the Rio Maria Farinha beds in Brazil.

Genus **SOLARIUM** Lamarck, 1799.

Solarium stephanephorum new species. Plate XIII, Figures 1, 2.

Description.—Shell circular in outline, depressed conic, being rather more flattened than the majority of the genus; whorls six, of which the uppermost are small and nuclear; volutions ornamented by (*a*) transverse, oblique, faint lines of growth, visible only with a lens; (*b*) coarser and finer raised spiral threads, not beaded. The sculpture of the last volution consisting of (counting from the suture towards the periphery) three or four fine, close-set spirals, bounded by a more prominent spiral, these occupying the flat area of the whorl; then follows a sloping area ornamented by two fine spirals followed by a stronger one, which with two following form the rounded keel of the shell; under surface as far as not obscured by the matrix is also ornamented by spiral threads.

Height of shell 7, greatest diameter 17 mm.

Remarks.—This simply but handsomely sculptured shell bears a considerable resemblance to flatter specimens of Heilprin's *S. cupolum* from the Lignitic of Alabama. But although the general type of sculpture is not unlike, the base and periphery of the Alabama shell is wholly different, the periphery having a sharp, overhanging keel while that of the Soldado shell is evenly and gently rounded. The other Solariums which resemble *S. stephanephorum* in shape have the beaded type of sculpture which shows a specific difference.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.
Geological horizon.—Lignitic Eocene.

Genus **AMPULLARIA** Lamarck, 1799.

Ampullaria luteostoma Swainson. Plate XIII, Figure 3.

Several broken shells of this species were found in the Barranca near Guanoco, Venezuela. These match exactly shells of the same species now living in the water near by, and our drawing shows the broken fossil shell (shaded) supplemented by a recent one (dotted line) of the same size.

Ampullaria luteostoma is very common in the streams and ditches in Venezuela. It shows great variation in color designs; some shells being a uniform yellowish-green, while others are variously banded with chocolate or reddish brown.

Locality.—The Barranca, along the Guanoco-Felicidad railway, Venezuela.
Geological horizon.—Pleistocene. A raised beach formation.

Ampullaria (Ceratodes) cornuarietis Linn. Plate XIII, Figure 4.

Remarks.—Like all the Ampullarian shells belonging to the section *Ceratodes* Guilding (*Marisa* Gray) this species is discoidal in form, resembling superficially *Planorbis.*

Ceratodes cornuarietis lives in Brazil, and is exceedingly common in Venezuela where it is much prized by the Guarauno Indians as an article of food. The writer has seen it in hundreds in the brackish water streams and ditches along the Guanoco-Felicidad railway. It varies greatly in its decoration of bands,—some shells being of a uniform amber color, while others are handsomely variegated with bands of reddish brown of various widths and patterns.

A few broken specimens of this species were found in the shell bank near Guanoco above the ditch in which the recent shells are living.

The fossil and recent forms are exactly alike, and the figure shows the fossil fragmentary shell (shaded) supplemented by a recent one of the same size (lined only).

Locality.—The Barranca, along the Guanoco-Felicidad railway, Venezuela.
Geological horizon.—The fossils are found in a raised beach of Quaternary age.

Genus **CALYPTRÆA** Lamarck, 1799.

Calyptræa aperta Solander. Plate XIII, Figure 5.

Trochus apertus Solander, Foss. Hant. p. 9, figs. 1, 2, 1766.
Calyptræa trochiformis Lamarck, Ann. du Mus., vol. 1, p. 385, 1802.

Calyptræa trochiformis Deshayes, Coq. fos. bas. Paris, II, p. 30, pl. 4, figs. 1, 2, 3, 1824.
Infundibulum urticosum Conrad, Fos. Shells Tert. Form., 1st ed., No. 3, p. 32, 1833.
Infundibulum trochiformis Conrad, Fos. Tert., 2d ed., p. 46, pl. 16, fig. 18, 1835.
Trochita alta Conrad, Wailes, Geol. Miss., p. 289, pl. XV, figs. 3a, 3b, 1854.
Calyptræa (Trochita) trochiformis Heilprin, Proc. Acad. Nat. Sci. Phila., vol. 31, p. 219, 1879.
? *Galerus olindensis* White, Arch. do Museu Nac. do Rio de Janeiro, vol. VII, pp. 167–168, pl. XVIII, figs. 15, 16, 1887.
Calyptræa trochiformis Dall (*pars*), Trans. Wagner Inst. Sci., vol. III, pp. 352–353, 1892.
Calyptræa trochiformis Vaughan, U. S. Geol. Surv., Bull. 142, p. 50, 1896.
Calyptræa aperta Harris, Bull. Am. Pal., vol. III, p. 84, pl. 11, figs. 13–16, 1899.
Calyptræa aperta Clark, Eocene Rept. Maryland Geol. Surv., p. 152, pl. XXVIII, figs. 4, 5, 1901.

Solander's original description.—"Trochus (*apertus*) testa gibboso-conica exasperata obliquata subtus concava, apertura angustata.

"Primo intuitu *Patellis* assimilatur illisque quæ *Labio interno* instructæ sunt, cfr. Linn. Syst. nat. n. 654–658. Specimina autem perfecta spiram ostendunt completam, *anfractus* licet pauciores quam in congeneribus; *Apertura* etiam magis contracta est.

"Testa magnitudine Juglandis sed depressior, sæpeque minor; tabula imposita conum formans *gibbosiusculum*, quo etiam a congeneribus differet; externe scabra, subtus leavis, concava.

"Apertura angustata, lateribus magis roduntatis quam in reliquis hujus generis."

Remarks.—This shell, which was first described from the Barton beds in southern England, is also in the Eocene of the Paris basin, and in that of the Atlantic and Gulf States of North America.

The Soldado shell corresponds closely to young specimens from Vicksburg, Mississippi.

In 1887 Dr. White described *Galerus olindensis* from the town of Olinda, and the Rio Maria Farinha beds, both in the State of Pernambuco, Brazil. This is probably identical wth *C. aperta*, although the peculiar sagging outward of the last whorl (which however was probably an individual and not a specific character) makes a positive identification of Dr. White's shell impossible.

The vertical as well as the geographical range of this species was wide, for it occurs in the Eocene, Oligocene and Miocene formations.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria, near the Serpent's Mouth.

Geological horizon.—Midway Eocene. Equivalent to the Midway of Alabama and of the Rio María Farinha beds, State of Pernambuco, Brazil.

Calyptræa centralis Conrad. Plate XIII, Figure 6.

Infundibulum centralis Conrad, Am. Jour. Sci., XLI, p. 348, 1841; Medial Tert., p. 80, pl. 45, fig. 5, 1845.
Trochita Collinsii Gabb, Jour. Acad. Nat. Sci. Phil., 2d ser. IX, p. 249, pl. 35, fig. 39, 1845.
Infundibulum Candeana d'Orb., Moll. Cuba, II, p. 190, pl. XXIV, figs. 28, 29, 1842.
Calyptræa centralis Dall, Trans. Wagner Inst. Sci., vol. III, pp. 353, 354, 1892.
Calyptræa centralis Martin, Maryland Geol. Surv., Miocene, p. 248, pl. LIX, figs. 2a, 2b, 2c, 1904.

Conrad's original description.—"Obtusely ovate, with fine concentric irregular lines; apex central."

Remarks.—This widely distributed species is found in the Oligocene of

Chipola, Florida, and of Costa Rica; it extends through the Miocene, Pliocene, and Pleistocene of the United States, and is now living on the coasts of North and South America from Cape Hatteras almost to the Straits of Magellan.

Dr. Guppy reports this species (as *Trochita candeana* d'Orb.) from the Pliocene and recent faunas of Trinidad.

The presence of this shell in the Brighton marl suggests a horizon not earlier than late Oligocene, as it is not known to have existed earlier than the Chipolan of Florida.

Locality.—Southern main road just south of Pitch Lake, Brighton, Trinidad, in a yellowish-brown ferruginous marl.

Geological horizon.—Upper Oligocene.

Genus **NATICA** Adanson, 1757.

Natica eminulopsis new species. Plate XIII, Figure 7.

Description.—Shell resembling smaller specimens of *N. eminula* Conrad, especially the variety found in the Lignitic Eocene of Wood's Bluff, Alabama,[82] but with a higher spire and more elongated body whorl; volutions four; perforation not covered by callus, characters of the aperture concealed by the indurated matrix.

Height of shell 12, greatest width 9 mm.

Remarks.—The writer is in some doubt whether this should be regarded as a variety of *eminula* rather than as a separate species. But as typical *eminula* is Claibornian Eocene, it seemed best to regard the Midway form as of the same group and a precursor of *eminula* but a distinct species.

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene.

Natica cf. semilunata Lea var. Plate XIII, Figure 8.

A shell of a *Natica* was found in the Soldado Lignitic fauna, which compares well with small specimens of a varietal form of *N. semilunata* from the Lignitic of Wood's Bluff, Alabama.[83]

The aperture of the Soldado shell is, however, concealed, and renders a definite comparison impossible. Yet it is very probable that the Soldado form is a variety of Lea's shell or else a closely related species.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Genus **AMAUROPSIS** Mörch, 1857.

Amauropsis caloramans new species. Plate XIII, Figure 9.

Description.—Shell of moderate size, ovate; substance thin and fragile, as shown where the shell is fractured; surface entirely smooth except for delicate

[82] See Harris, Bull. Am. Pal., vol. III, p. 88, pl. 11, fig. 22, 1899.
[83] See Bull. Am. Pal., vol. I, p. 86, pl. II, figs. 18–20, 1896.

microscopic lines of growth; number of known whorls three, evenly rounded, full, slightly shouldered at the upper portion; suture impressed, marked by a narrow channel; aperture and characters of the columella concealed by the silicious matrix.

Height of shell approximately 30, greatest width 21 mm.

Remarks.—The only other *Amauropsis* described from the Midway Eocene is *A. tombigbeensis* Harris from Alabama, which is wholly unlike the Soldado shell. There is also in the Paleontological Museum of Cornell University an undescribed Midway species somewhat like the latter but smaller. The nearest ally of the Soldado shell is *A. perovata* Conrad from the Claibornian Eocene.[84]

It is a curious fact that all the living species of *Amauropsis* are in Arctic and Antarctic seas, yet a number of Tertiary species lived like the Soldado shell in tropical and subtropical waters. Has the genus fled to the less crowded frigid oceans to escape the pressure of competition in the tropics?

Locality.—Bed No. 2, Soldado Rock, Gulf of Paria.

Geological horizon.—Midway Eocene.

Amauropsis ? guariqueenensis new species. Plate XIII, Figure 10.

Remarks.—In a limestone ravine near Guariqueen, Venezuela, there are traces of quantities of the remains of large gastropod shells.

Several species are represented; but it is impossible to separate the fossils from the rock. Hundreds of sections cutting through the shells at various planes were observed on slabs of the limestone, but not a single complete specimen was to be had.

A drawing is given of the best specimen obtained after treating with various acids in the unsuccessful attempt to disclose the whorls. The shells are all turned to a blackish crystalline spar, and form an integral part of the excessively indurated limestone.

The general form of the shell indicates a large species of *Amauropsis*. Others, with very oblique outlines, suggest such forms as *Neritidomus* from the Brazilian Cretaceous figured in White's monograph.

Locality.—Along the trail from Pitch Lake to Guariqueen, Venezuela, in a limestone gorge.

Geological horizon.—Probably Cretaceous.

Amauropsis smithiana new species. Plate XIII, Figures 11, 12, 13.

Description.—Shell of moderate size, varying considerably in that respect; substance thin and fragile; number of whorls known, five, very convex, gently rounded, slightly shouldered beneath the suture; shell entirely without sculpture, perfectly smooth, suture impressed; aperture nearly semi-lunar; callus very thin.

Approximate height of largest specimen 18, greatest breadth 17 mm.

Remarks.—This is the commonest species in the Lignitic fauna of Soldado.

[84] Bull. Am. Pal., vol. I, p. 49, pl. 1, fig. 1.

It varies in size, but the specimens all show the same characteristics in other respects and apparently are all the same species.

An *Amauropsis* was described by Professor Harris from the upper Claibornian Eocene of Texas[85] as *A. singleyi*. This species is closely allied to *A. smithiana*.

The writer takes great pleasure in naming this shell in honor of Mr. Edward Eggleston Smith, of the Geological Survey, Washington, D. C.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Genus **LIOTIA** Gray, 1842.

Liotia lillianæ new species. Plate XIII, Figure 14.

Description.—Shell small, rather solid, depressed-conic; whorls convex, four, of which the uppermost is nuclear and smooth, the rest being ornamented with granulated threads, last volution with three such granulated or finely beaded threads followed by a much stronger basal carina, and that by a subbasal ridge about equal in size to the carina; surface more or less reticulated by the intersection of the revolving beaded threads by transverse, oblique lines of growth; suture deeply channelled.

Height of shell 3, greatest breadth 4 mm.

Remarks.—This pretty shell is of much the same shape and size as the only known Eocene species, *L. granulata* Lea,[86] from the Claiborne and Lignitic of the Southern states. But on comparing it with specimens of Lea's species, the sculpture is found to be quite different.

The genus *Liotia* was rare in the Eocene, but became more abundant in the later Tertiaries of Florida; and is now represented by about a dozen species in the recent Floridian and Antillean faunas. It also flourishes on the coasts of Australia and the Philippines.

The Soldado species is dedicated to Mrs. E. E. Smith, of Washington, D. C.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Class SCAPHOPODA.

Genus **DENTALIUM** (Aldrovande, 1618) Linnæus, 1758.

Dentalium microstria Heilprin. Plate XIII, Figure 15.

Dentalium microstria Heilprin, Proc. Acad. Nat. Sci. Phila., p. 375, pl. 20, fig. 3, 1880.
Dentalium microstria Dall, Trans. Wagner Inst., vol. III, pp. 438, 439, 1892.
Dentalium microstria Aldrich, Bull. Am. Pal., vol. I, p. 55, pl. i, fig. 6, 1895.
Dentalium microstria Harris, Bull. Am. Pal., vol. III, pp. 3–4, pl. i, fig. 1, a, 1899.

Heilprin's original description.—"Shell slender, considerably curved and greatly attenuated, faintly striated, the striæ most conspicuous on the attenuated portion; posterior aperture entire, there being no fissure; anterior aperture circular.

"Length 1½ to 2 inches."

[85] Proc. Acad. Nat. Science Phila., p. 84, pl. 9, fig. 12, 1895.
[86] Cont. to Geol., p. 122, pl. 4, fig. 111, 1833.

Remarks.—A single *Dentalium* shell was found at Soldado. On comparing this with a large number of *D. microstria* from the Lignitic of Alabama, it is found to resemble them very closely, the only apparent difference being that the microscopic striæ on the Soldado shell are slightly more pronounced and a trifle more close-set than those on the Alabama shells. They appear to be the same species, although the Soldado shell should perhaps be classed as a variety.

Locality.—Bed No. 8, Soldado Rock, Gulf of Paria.

Geological horizon.—Lignitic Eocene.

Class CEPHALOPODA.

Genus AMMONITES (Breyn, 1732) Lamarck, 1801.

Ammonites cf. mosqueræ Karsten. Plate XIII, Figure 16.

Remarks.—Associated with *Inoceramus plicatus* (Orb.) Karsten (which is apparently identical with *Inoceramus labiatus* Schlotheim) in the dark, cherty, hard layers of the Cretaceous limestones near Guanoco, Venezuela, are a number of small, worn Ammonites.

Dr. Stanton, of the United States Geological Survey, well-known as the leading American Cretaceous paleontologist, kindly examined a number of the latter and compared them in general form and sculpture with Karsten's *Ammonites mosqueræ* and *A. barbacoensis*. Dr. Stanton remarked in his letter, "Unfortunately, your specimens do not show either the sutures or the character of the ventral margin, and it is therefore impossible to assign them to their proper genera. Their form and sculpture—so far as it is preserved in these specimens—are practically duplicated in the genera *Schlœnbachia*, *Prionotropis*, etc., which are common in the lower part of the Upper Cretaceous and are represented by similar types as low as the Gault."

On comparing the specimen figured with Karsten's *A. mosqueræ*[87] the general type of ornamentation is seen to be the same. It is very likely this species, for both *A. mosqueræ* and *barbacoensis* were found by Karsten with *Inoceramus plicatus* in the Barbacoas limestone.

Locality.—Ravine on the right hand side of the trail going from Guanoco to Hurupu, Venezuela, just above Rio Colorado. Latitude approximately 10° 8′ North; longitude approximately 3° 59′ 6″ East of Caracas.

Geological horizon.—Upper Cretaceous, probably equivalent to the European Turonian, or the Benton of the western United States,—certainly not lower than the Gault (Stanton).

Class BRACHIOPODA.

Genus TEREBRATULA (Llhwyd, 1699) Klein, 1753.

Terebratula stantoni new species. Plate XIII, Figures 17, 18.

Description.—Shell of moderate size, oblong, substance thin and fragile; beak slightly incurved, terminated by a large, circular foramen; surface orna-

[87] Géol. de l'ancienne Colombia Bolivarienne, pl. IV, figs. 4a, 4b, 1886.

mented only by faint lines of growth and very delicate, microscopic, radiating striæ, otherwise entirely smooth; convexity of dorsal and ventral valves nearly equal.

Height of a rather large shell 20, greatest breadth 18, greatest diameter 13 mm.

Remarks.—At first glance this species resembles Dr. Guppy's *T. lecta* from the San Fernando beds, but the basal margin of that shell is somewhat sinuate and pointed, while the Soldado species is truncate, and the hinge margin is also straighter than in *lecta*, nor is there the flattening of the ventral valve noted by Dr. Guppy in his species.

This was one of the most abundant shells in the Soldado fauna. Trinidad seems to have been the favorite haunt of the genus *Terebratula* during the Tertiaries, for this is the fourth species described from that island. The genus has lived on from the Devonian to the recent seas.

This is the first species described from the Lignitic horizon.

The writer takes pleasure in naming this shell in honor of Dr. Stanton, as a slight appreciation of his kindness in identifying the Cretaceous fossils from Hurupu, Venezuela.

Locality.—Bed No. 8, Soldado Rock, near the Serpent's Mouth, in the Gulf of Paria.

Geological horizon.—Lignitic Eocene. Equivalent to the Lignitic of Alabama.

Class VERMES.

Genus SERPULA.

Serpula clymenioides Guppy. Plate XIII, Figures 20–22.

Spirorbis clymenioides Guppy, Quart. Jour. Geol. Soc., vol. XXII, p. 584, pl. XXVI, fig. 10, 1866.
Spirorbis clymenioides Guppy, Geological Magazine, new series, Decade II, vol. I, p. 444, 1874.

Guppy's original description.—"Tube coiled, discoidal, compressed; whorls usually three to four, flattened or even fused together, with sinuo-radiate lines of growth; periphery carinate; aperture constricted, circular; nucleus with an obsolete aperture nearly as large as the terminal one.

"The nearest species to this is *S. spirulæa*, Lam. (*Spirulæa nummularis* Schlot), from which the present species may be distinguished in never having the last whorl produced or separated.

"San Fernando beds, Trinidad. Specimens frequently occur in the cherty nodules, containing immense numbers of *Orbitoides mantelli* and *Nummulina*."

Remarks.—This odd tube, simulating a helix-like molluscan shell, is made by a worm of the suborder *Tubicola* (*Sedentaria*) of the genus *Serpula* Linnæus. This includes the majority of the fossil tubicolous Annelids. They build firm, irregularly twisted, or sometimes spirally enrolled, free or adherent calcareous tubes, frequently clustered in large numbers. The genus began in the Silurian, and is rare throughout the Paleozoic; but becomes very common in the Lower Cretaceous, and its recent distribution is world wide. *S. spirulæa* Lamarck, the form most closely allied to that from Trinidad, is an abundant and characteristic Eocene species of southern Europe.

Serpula clymenioides is quite common in the Foraminiferal beds of Farallon Rock, where Mr. Veatch succeeded in finding nearly a dozen shells. They were associated with the curious crustacean carapace of *Ranina porifera* Woodward and a number of sea urchins.

Locality.—Farallon Rock (also called Johnson's Island), near San Fernando, Trinidad, in the Gulf of Paria.

Geological horizon.—Lower Oligocene. Approximately equivalent to the San Fernando beds of Trinidad, and probably to the Vicksburgian of Mississippi.

Class CRUSTACEA.

Genus RANINA.

Ranina porifera Woodward. Plate XIII, Figure 23.

Ranina porifera Woodward, Quart. Jour. Geol. Soc. London, XXII, pp. 591–592, pl. XXVI, fig. 18, 1866.
Ranina porifera Guppy, Geol. Mag., p. 443, 1874.

Woodward's original description.—"A specimen of a Crustacean placed in my hands for examination by my friend Mr. R. Lechmere Guppy, from the Tertiary formation of Trinidad, proves to be a portion of the dorsal surface of the carapace of a Brachyurous Decapod—nearly approaching the *Anomura*—belonging to the subsection *Notopoda* and the genus *Ranina*.

"The species of this genus (which was established by Lamarck in 1801) are not only most singular in form, but they are of special interest to the paleontologist as occurring in the Nummulitic Limestone of Bavaria, Austria and Italy, Asia Minor, Scinde, and the West Indies (Trinidad), and also in the Oligocene of Germany and the Miocene of Turin. Nor has the genus now disappeared; for at the present day it is represented by the *Ranina dentata* of Latreille, which is found living in the Sandwich Islands, the Moluccas, the Mauritius, and Japan,[88] whilst a nearly allied genus, the *Raninoides*, Edw., is found living in the Philippine Islands, and Trinidad, having been collected in this latter locality by Mr. Guppy.

"The *Raninæ* are all burrowing forms of Crustacea living for the most part in deep water, buried in sand or mud, for digging in which their limbs are most admirably adapted.

"Unfortunately none of the appendages are preserved in the specimen under consideration; but all the species of this genus are curiously sculptured upon the dorsal surface of their carapaces, and the ornamentation is extremely characteristic of the group. It consists of irregular transverse pectinated ridges, sometimes interspersed with small punctuations, the ridges being more or less curved and intercalating with one another.

"In Prof. Reuss' work[89] these peculiarities are very well shown, but neither in these nor in the various specimens which I have been able to examine can I detect the same ornamentation as that observable in the *Ranina* from Trinidad.

[88] De Haan, Siebold's Fauna Japonica, 1833, p. 139, t. 34, 35.
[89] Foss. Krabben der k. k. Akad. der Wissenschaften, Wien.

"Each minute point forming the pectinate border to the several ridges has a small indented pit near its extremity, which has suggested the specific name *porifera*. It is to be hoped, however, that more perfect specimens will reward the zealous labors of Mr. Guppy, as the determination of species, offering such meagre characters as the one now noticed, is by no means safe, except in very peculiar and well-marked forms, such as the species of the genus *Ranina*."

Type locality, San Fernando beds, Trinidad. Later the species was found at St. Bart's.[90]

Remarks.—Woodward adds to his interesting description that in spite of the wide distribution of the genus in the old world ten species only are known to him. These range from the Eocene to the recent period.

The specimen now under consideration was collected by Mr. Arthur C. Veatch at Farallon Rock, off San Fernando, in the Gulf of Paria. Under a lens the minute pores characteristic of the species bordering the pectinated ridges of the carapace show most beautifully, and leave no doubt that this and the San Fernando specimen are the same species.

On Farallon Rock *Ranina porifera* is associated with masses of Foraminifera, with echinoderms and with the curious spiral worm tube, *Serpula clymenioides* first described by Dr. Guppy from the San Fernando beds. Thus the fauna of Farallon Rock and San Fernando have much in common. This is quite surprising, as, though the localities are not distant from one another, the lithological characters of the beds are wholly different. The San Fernando beds are black and highly asphaltic, while those of Farallon Rock in which these fossils occur are a fine yellowish grey sandy marl.

Locality.—Farallon Rock (also called Johnson's Island), near San Fernando, Trinidad, in the Gulf of Paria.

Geological horizon.—Lower Oligocene. Approximately equivalent to the San Fernando beds, and probably to the Vicksburgian of Mississippi.

Class ECHINOIDEA.

Genus ECHINOLAMPAS Gray.

Echinolampas ovumserpentis Guppy.

Echinolampas ovum-serpentis Guppy, Quart. Jour. Geol. Soc. London, vol. XXII, p. 300, pl. XIX, figs. 4–6, 1866.
Echinolampas ovumserpentis Guppy, Geol. Mag., p. 444, 1874.

Guppy's original description.—"Test oval, subcylindrical or nearly circular, wider behind than before, slightly rostrated anteriorly, and truncate posteriorly, sometimes having a tendency to become polygonal; ambulacra raised, petaloid, open at the ends, extending nearly to the tumid margins, the pores connected by an oblique groove; base convex, except towards the mouth, where it becomes somewhat concave; dorsum rather evenly convex; ambulacral summit subcentral; anus small, circular, situate between the peristome and the margin, much nearer to the latter than the former.

[90] Guppy, Geol. Mag., p. 443, 1874.

"This seems to be an extremely variable species, both as to general shape and as to the form of the mouth. It is distinguished from the preceding (*E. lycopersicus* Guppy) by its small circular vent and wider ambulacra. The mouth is usually subpentagonal, but occasionally becomes transversely oval. Some examples which approach the circular form have a tendency to become subconical.

"San Fernando, Trinidad."

Remarks.—Among the Echinoderms from Farallon Rock was one exactly like Dr. Guppy's figure 4*b*.

Locality.—Farallon Rock, near San Fernando, Gulf of Paria.

Geological horizon.—Lower Oligocene. Equivalent to the San Fernando beds of which this horizon appears to be a continuation.

EXPLANATION OF PLATES V–XIII.

PLATE V.

FIG. 1. *Ostrea abrupta* d'Orb. var.? Valve showing plicated exterior. Venezuela. Cretaceous. Height 25 mm. ..... Page 40
2. *Ostrea abrupta* d'Orb. var.? Interior of a larger valve. Venezuela. Cretaceous. Height 45 mm. 40
3. *Ostrea puelchana* d'Orb. Small variety. Height 47 mm. Union Estate, Brighton, Trinidad. Oligocene 40
4. *Ostrea puelchana* d'Orb. Same shell as 3. Interior of flat valve 40
5. *Ostrea puelchana* d'Orb. Same shell. Interior of convex valve 40
6. *Ostrea thirsæ* Gabb. Convex valve. Height 28 mm. Soldado Rock. Lignitic Eocene 39
7. *Ostrea thirsæ* Gabb. Same shell, lateral view 39
8. *Ostrea thirsæ* Gabb. Flat valve. Height 20 mm. Soldado Rock. Lignitic Eocene .. 39
9. *Ostrea puelchana* d'Orb. Large variety. Height 135 mm. Union Estate, Brighton, Trinidad. Oligocene 40
10. *Ostrea puelchana* d'Orb. Same shell, lateral view 40
11. *Ostrea crenulimarginata* Gabb. Smooth and plicated valves. Soldado Rock. Midway Eocene 36

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FIG. 1. *Ostrea crenulimarginata* Gabb. Exterior of left valve. (After Aldrich and Harris.) Alabama ..... Page 36
2. *Ostrea crenulimarginata* Gabb. Interior of left valve. (After Aldrich and Harris.) Alabama 36
3. *Ostrea crenulimarginata* Gabb. Interior of unusually rounded form. (After Aldrich and Harris.) Alabama 36
4. *Ostrea crenulimarginata* Gabb. Young shell, rounded variety. Height 25 mm. Soldado Rock. Midway Eocene 36
5. *Ostrea cynthiæ* n. sp. Flat, upper valve resting on convex lower. Height 140 mm. Showing commencement of concentric deposits of silicon. Soldado Rock. Midway Eocene 37
6. *Ostrea thalassoklusta* n. sp. Height 23 mm. Soldado Rock. Midway Eocene 39
7. *Ostrea* cf. *percrassa* Conrad and *compressirostra* Conrad. Shell completely disguised by concentric silicious deposits. Length 130, height 90 mm. Soldado Rock. Midway Eocene 37

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3. *Plicatula* cf. *torta* Gabb. Rio Grande, Venezuela. Cretaceous 41

4. *Spondylus* sp. indet. Height of fragment 31 mm. Soldado Rock. Lignitic Eocene 41
5. *Pecten* sp. indet. Cast of interior. Height 6 mm. Brighton, Trinidad. Oligocene
6. *Perna obliqua* Lam. Young shells. Burrowing in solid rock. Height of shell 10 mm. Black Rock, Gulf of Paria. Recent 41
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9. *Modiola* cf. *alabamensis* Aldrich. Length 23 mm. Soldado Rock. Lignitic Eocene 43
10. *Arca* (*Argina*) *schultzana* n. sp. Length 35 mm. Gulf of Paria, Brighton, Trinidad. Recent 46
11. *Arca* (*Argina*) *schultzana* n. sp. Interior of same valve showing hinge 46
12. *Arca* (*Argina*) *schultzana* n. sp. Lateral view, same valve 46
13. *Arca* (*Cunearca*) *chemnitzioides* n. sp. Mould in ferruginous marl. Lateral view showing unequal valves. Brighton. Oligocene 44
14. *Arca* (*Cunearca*) *chemnitzioides* n. sp. Internal mould showing high, triangular form. Length 22 mm. Brighton. Oligocene 44
15. *Arca* (*Cunearca*) *chemnitzioides* n. sp. From a gutta-percha impression showing surface sculpture. Same locality 44
16. *Arca* sp. indet. Length of fragment 18 mm. Brighton. Oligocene 47

PLATE VIII.

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2. *Arca* (*Argina*) *billingsiana* n. sp. Length 31 mm. Brighton, Trinidad. Upper Oligocene 45
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4. *Arca* (*Argina*) *brightonensis* n. sp. Length 24 mm. Brighton. Oligocene 46
5. *Arca* (*Argina*) *brightonensis* n. sp. Same shell, lateral view 46
6. *Arca* (*Argina*) *brightonensis* n. sp. Interior of same shell showing hinge characters .. 46
7. *Arca* (*Argina*) *pariaensis* n. sp. Length 24 mm. Gulf of Paria between La Brea and San Fernando. Recent 47
8. *Arca* (*Argina*) *pariaensis* n. sp. Interior of same shell showing hinge characters 47
9. *Arca* (*Argina*) *pariaensis* n. sp. Lateral view of same shell 47
10. *Arca* (*Noetia*) *sheldoniana* n. sp. Length 15 mm. Brighton, Trinidad. Upper Oligocene 43
11. *Arca* (*Noetia*) *sheldoniana* n. sp. Interior of same valve 43
12. *Cucullæa harttii* Rathbun. Length 29 mm. Soldado Rock, Gulf of Paria. Midway Eocene 48
13. *Glycymeris* (*Axinea*) *viamediæ* n. sp. Height 16 mm. Soldado Rock. Midway Eocene 49
14. *Venericardia crucedemaionis* n. sp. Length approximately 7 mm. Soldado Rock. Lignitic Eocene 51
15. *Venericardia planicosta* Lamarck. Width 55 mm. Soldado Rock. Midway Eocene 51
16. *Venericardia planicosta* Lam. Interior mould with fragmentary margin of exterior. Width 48 mm. Soldado Rock. Midway Eocene 51
17. *Venericardia thalassoplekta* n. sp. Height 19 mm. Soldado Rock. Midway Eocene 53
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3. *Cardita* (*Carditamera*) *virginiæ* n. sp. Interior mould of above shell 53
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8. *Meretrix* cf. *nuttalliopsis* Heilprin. Length 26 mm. Soldado Rock. Lignitic Eocene. 55

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10. *Callista mcgrathiana* Rathbun. Length 24 mm. Soldado Rock. Midway Eocene 57
11. *Callista mcgrathiana* var. *rathbunensis* new var. Length 21 mm. Soldado Rock. Midway Eocene 58
12. *Pitaria* (*Lamelliconcha*) *circinata* Born. Young shell. Length 10 mm. Brighton, Trinidad. Upper Oligocene 56
13. *Pitaria* (*Lamelliconcha*) *circinata* Born. Interior of same shell 56
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20. *Chione paraensis* White var. Length 8 mm. Soldado Rock. Midway Eocene..... 60
21. *Venerupis atlantica* n. sp. Length of fragment 13 mm. Soldado Rock. Lignitic Eocene 60
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26. *Corbula* sp. indet. Interior moulds. Length 11 mm. Brighton. Oligocene..... 64
27. *Corbula* sp. indet. Lateral view of same mould..... 64
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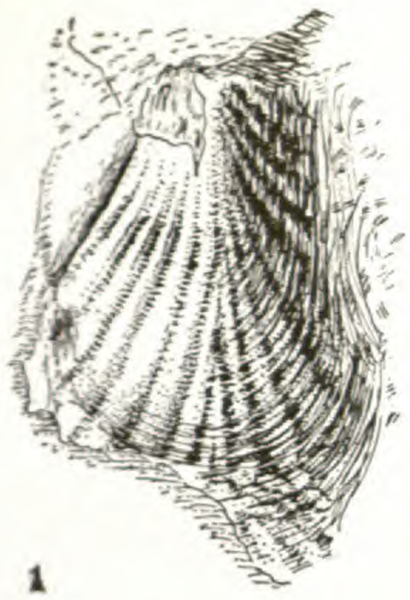

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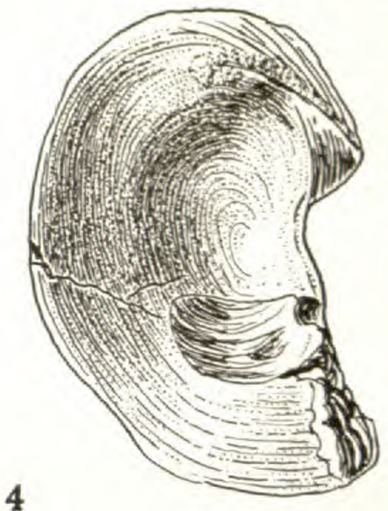

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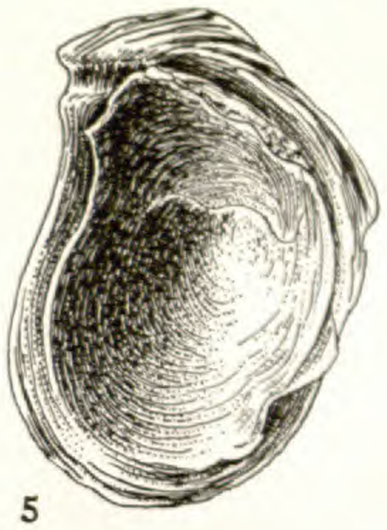

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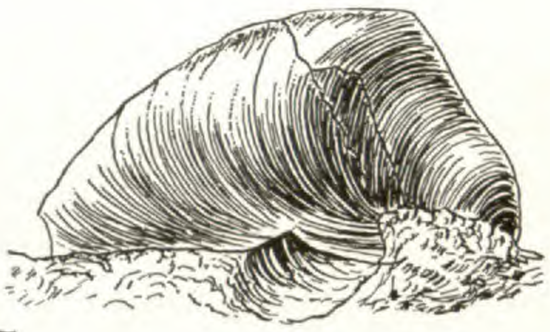

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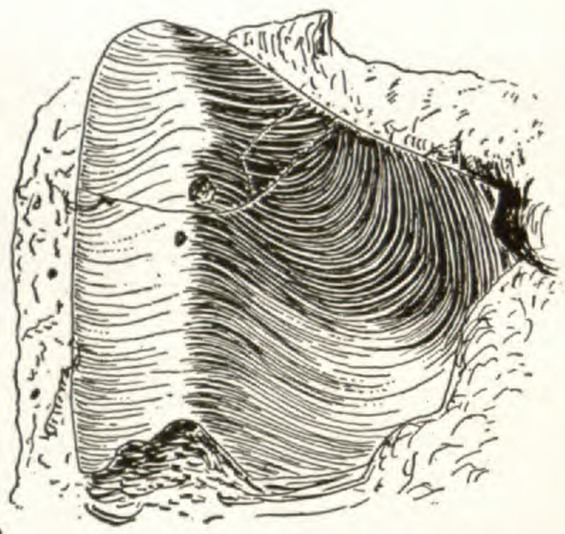

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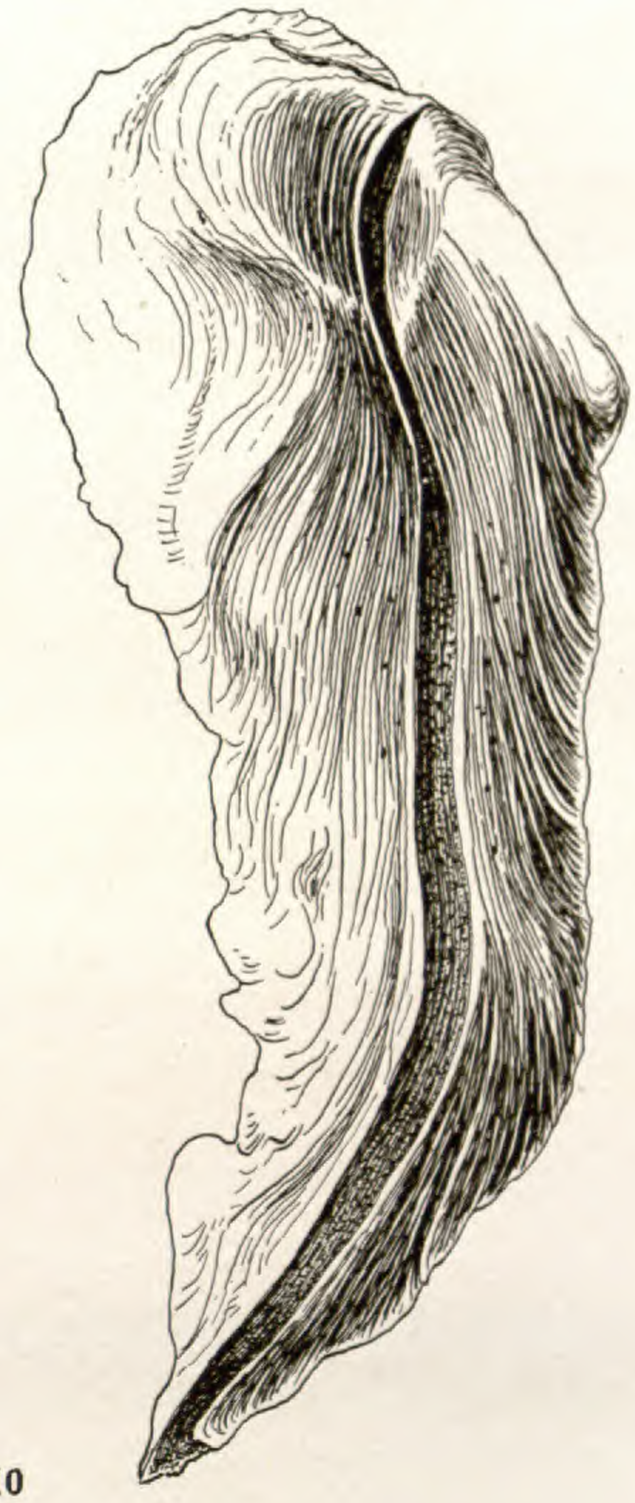

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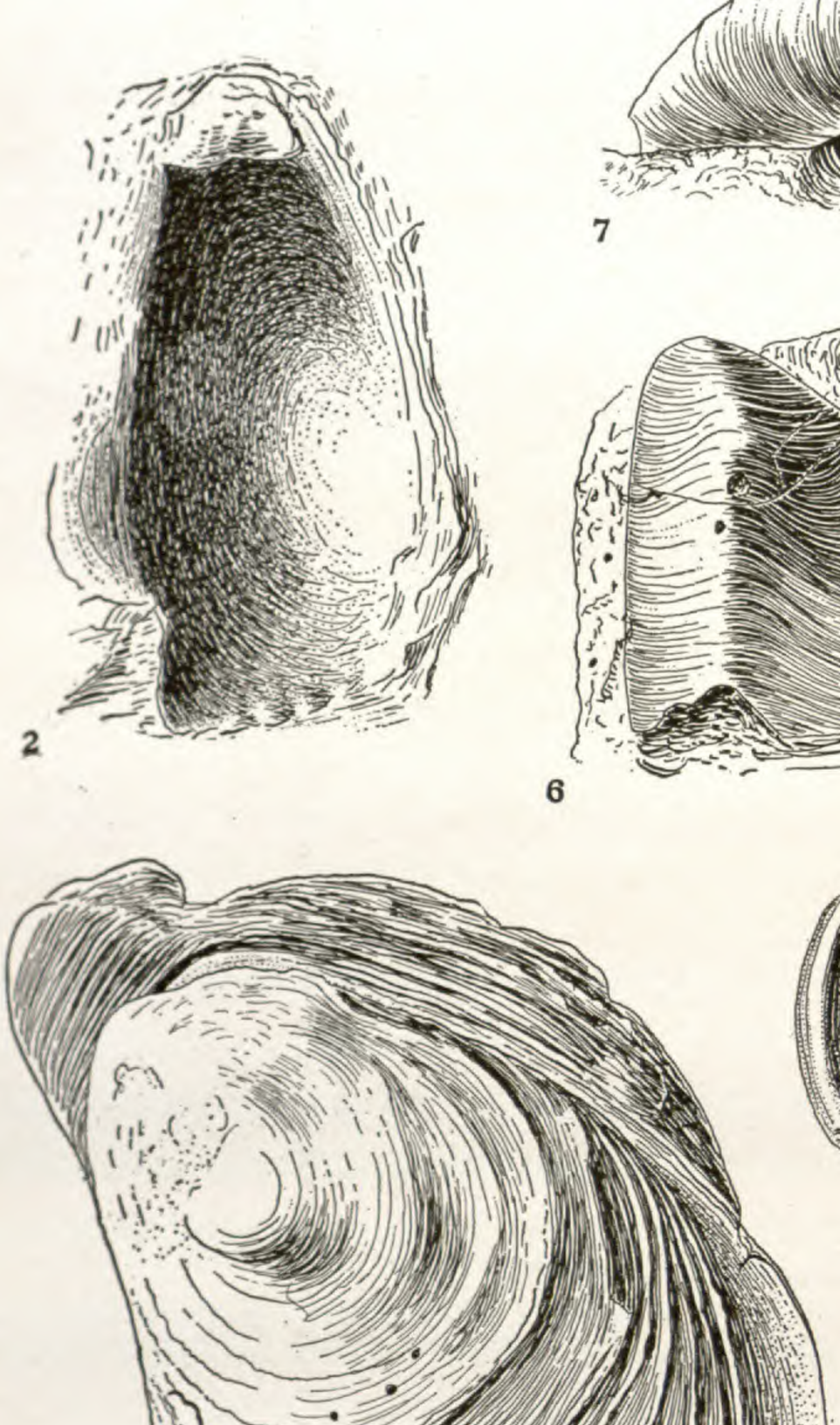

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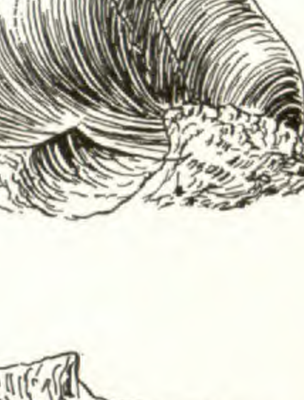

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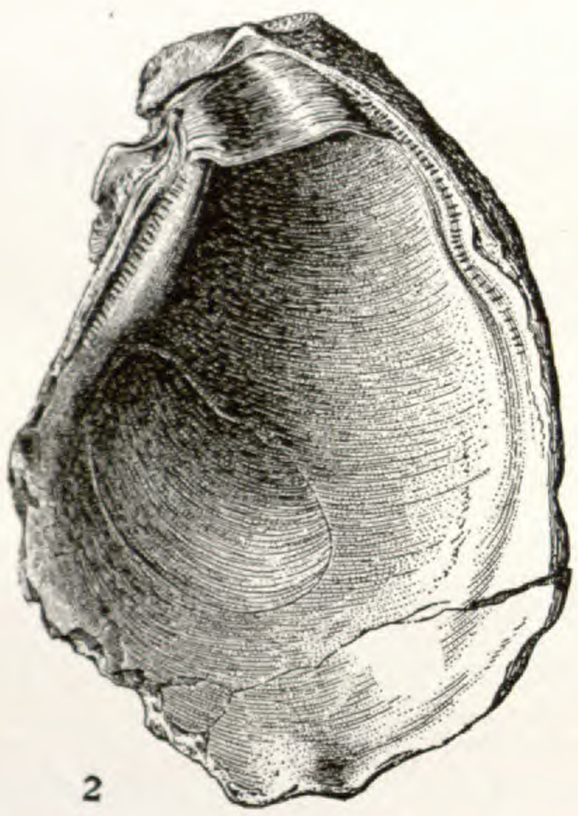

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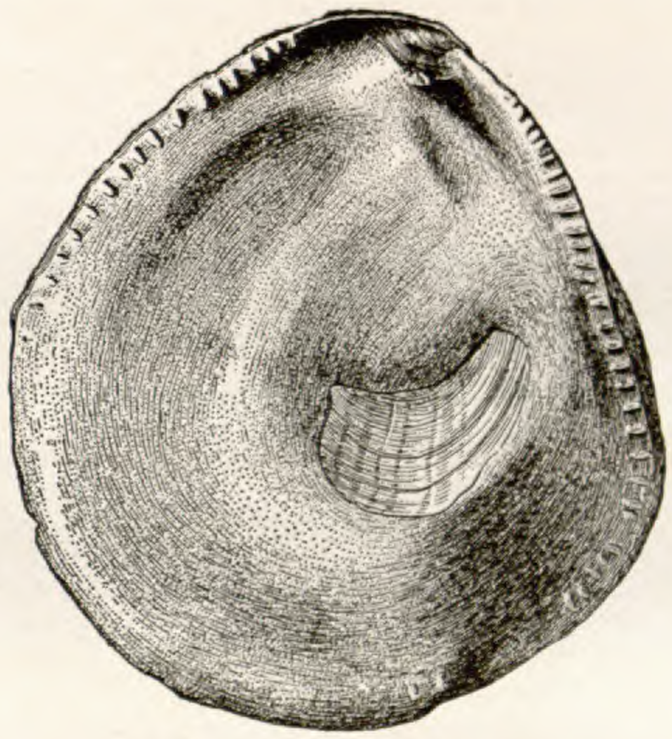

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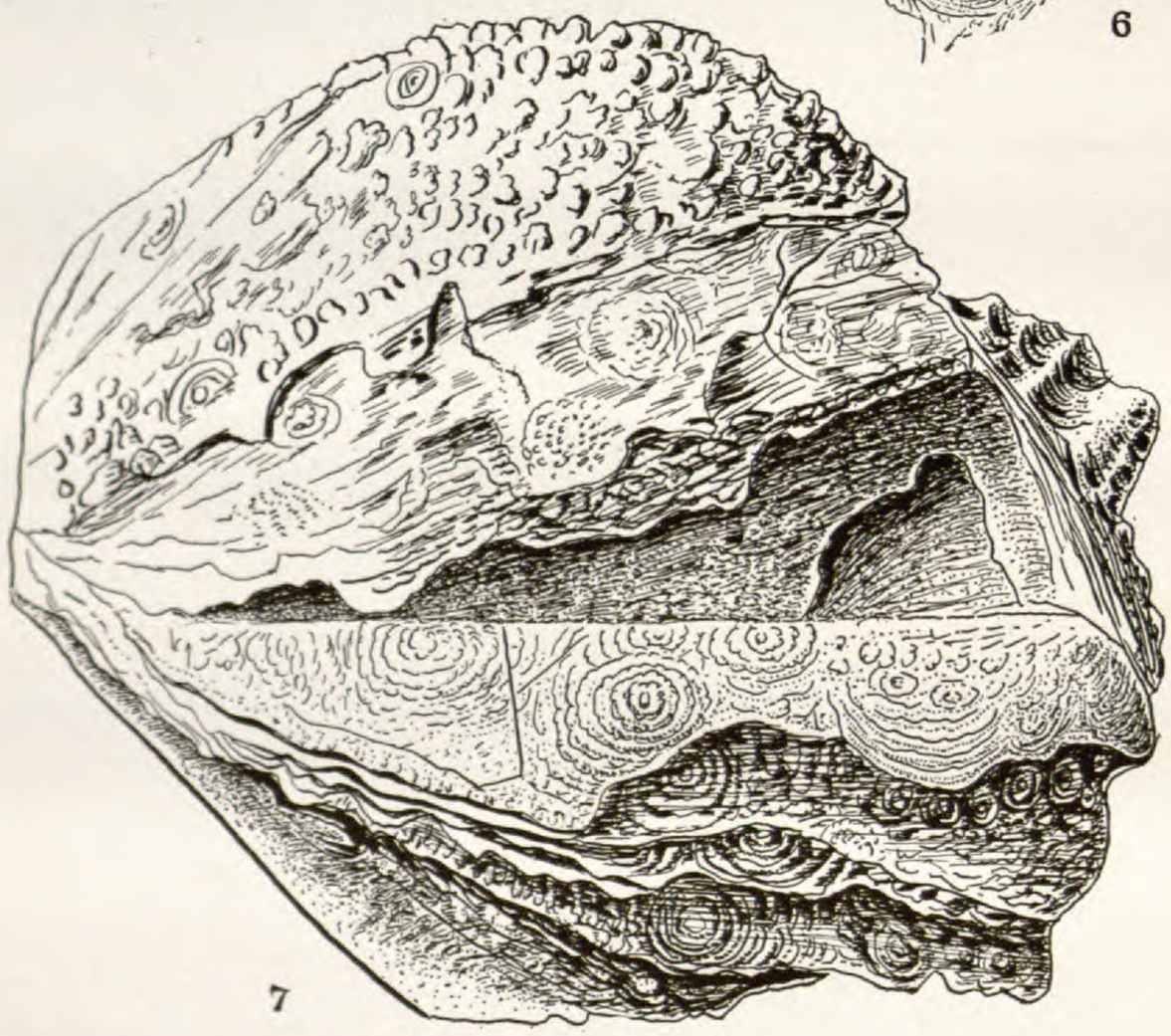

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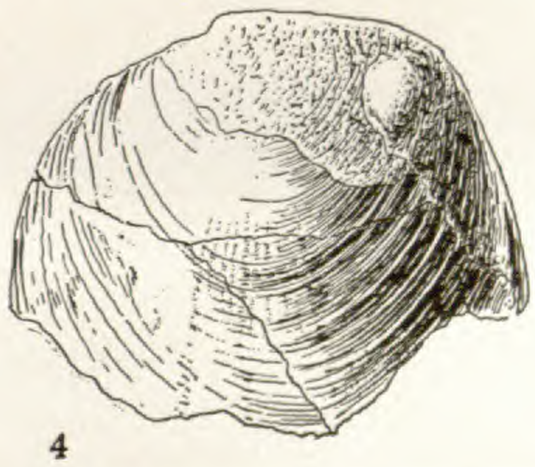

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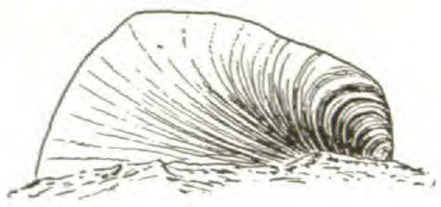

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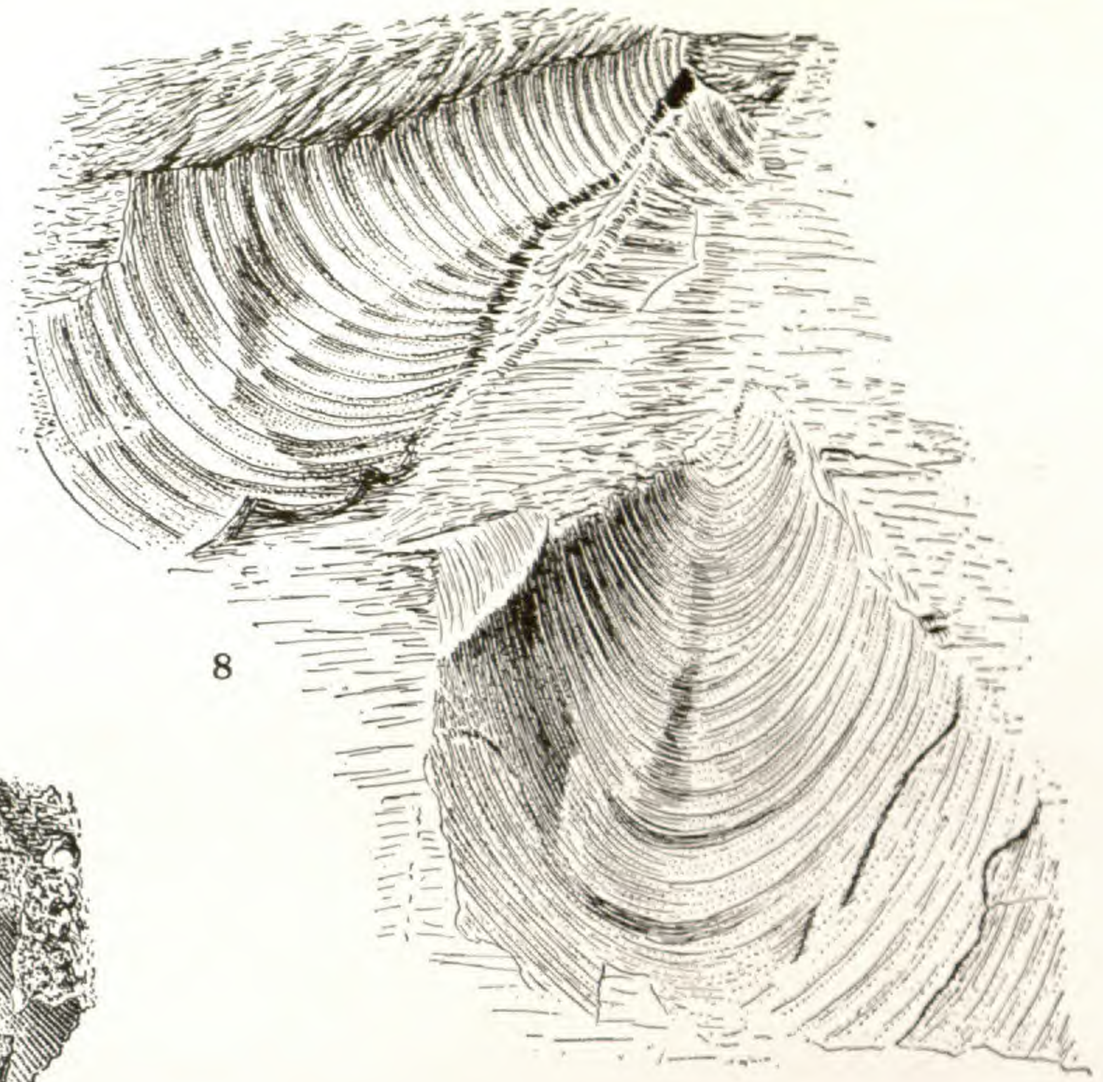

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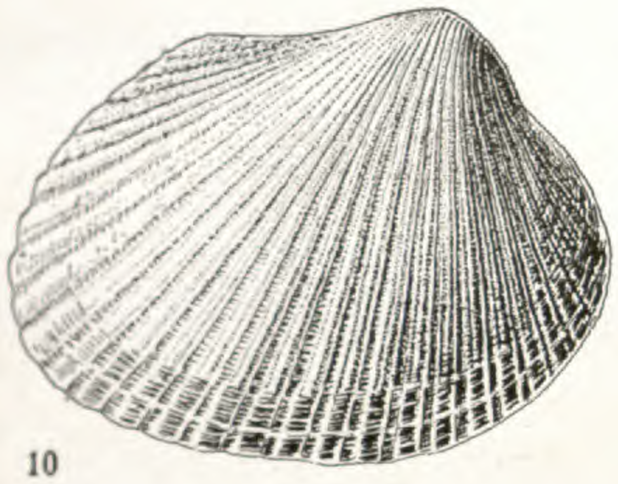

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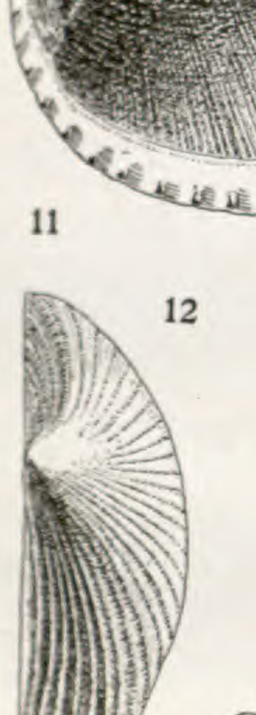

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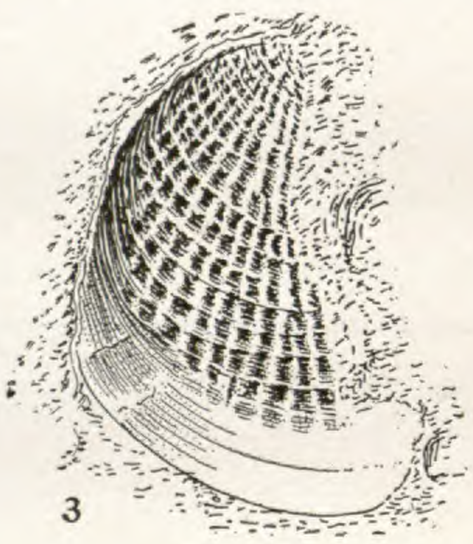

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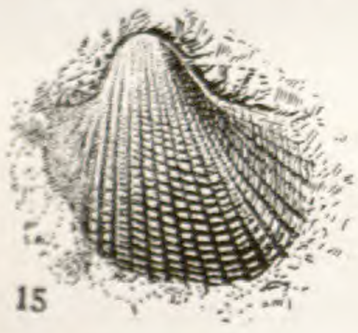

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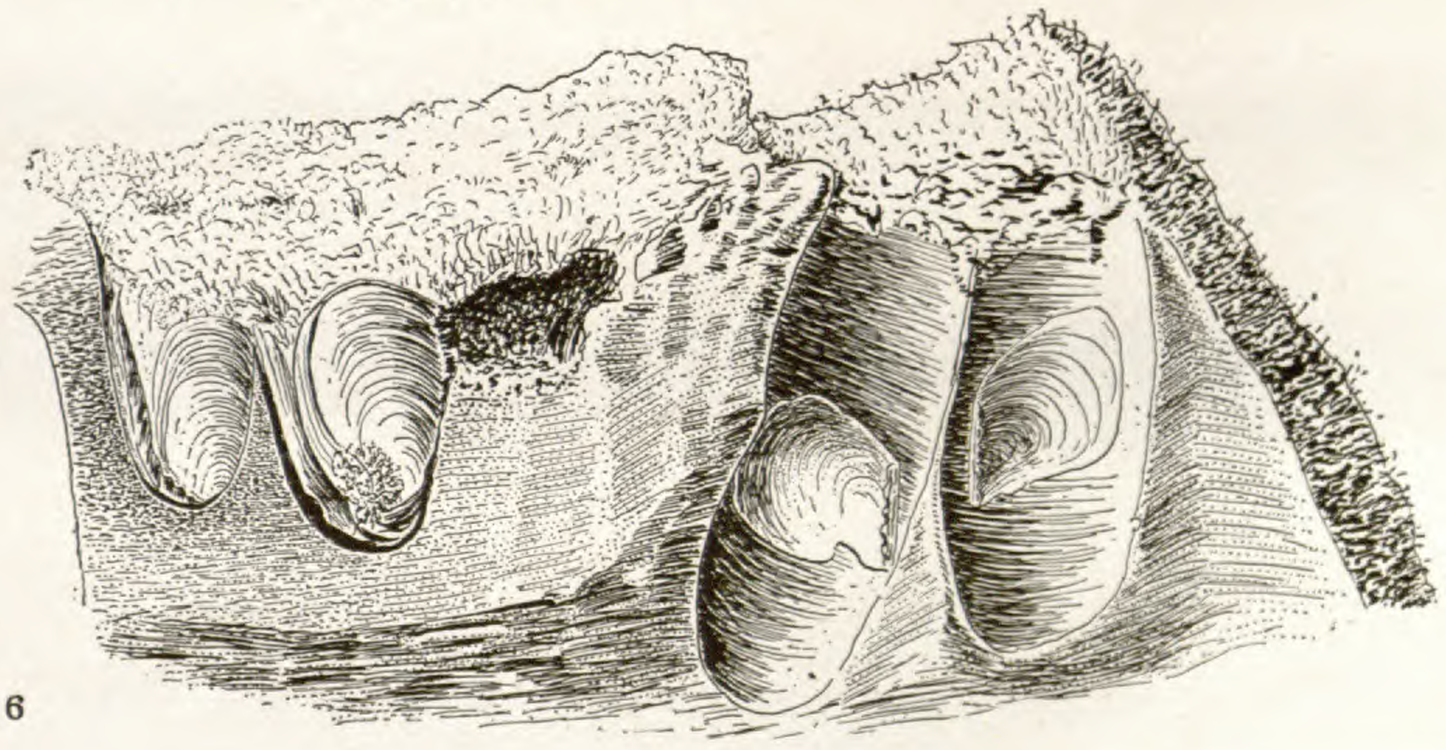

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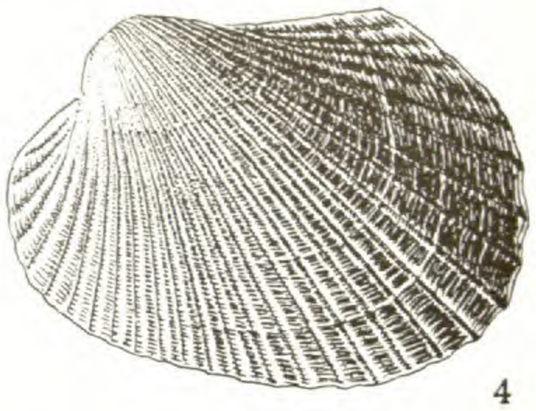

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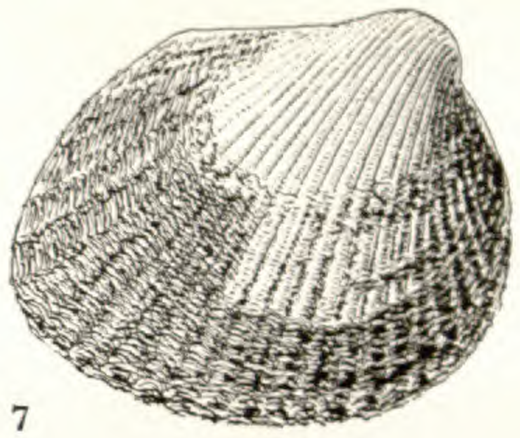

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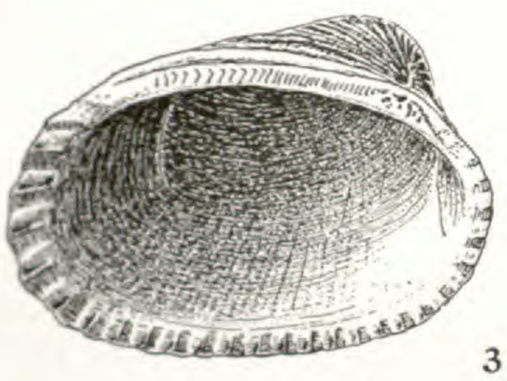

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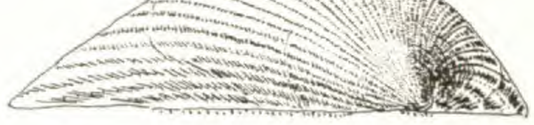

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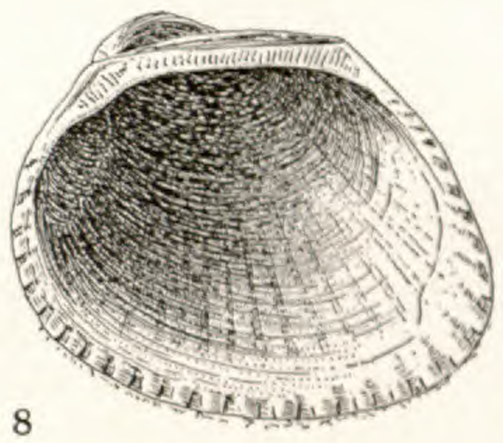

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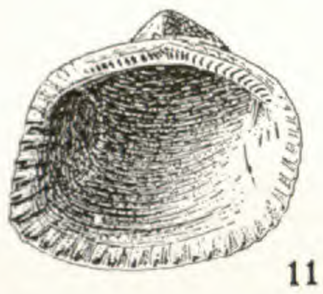

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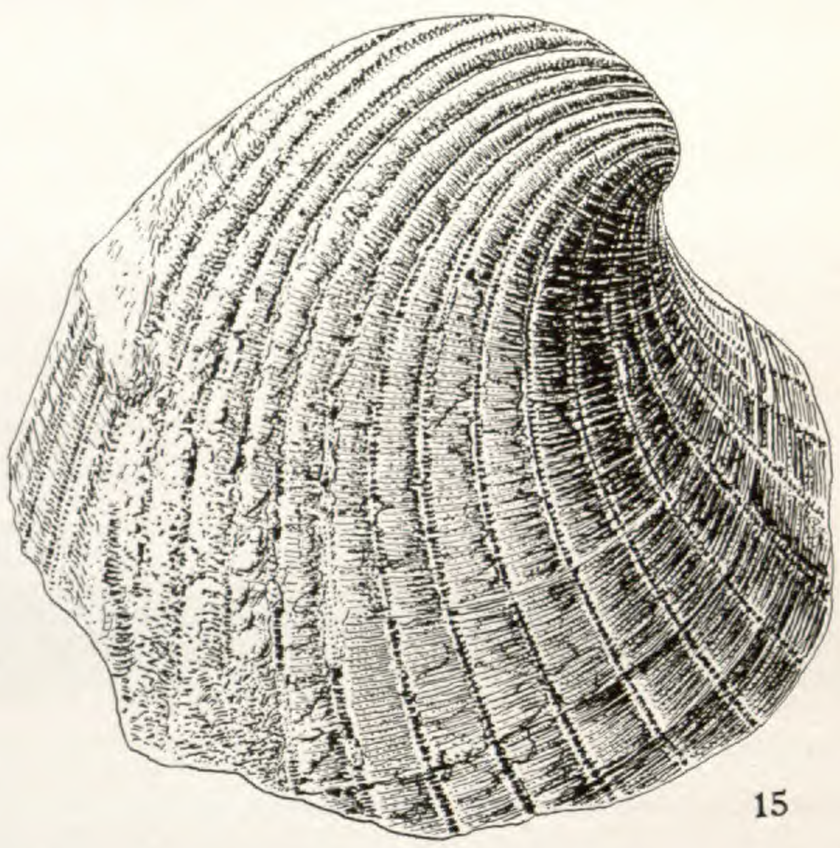

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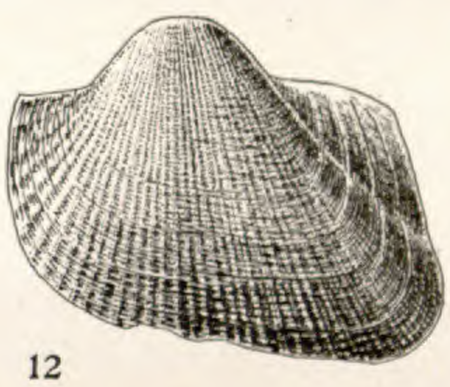

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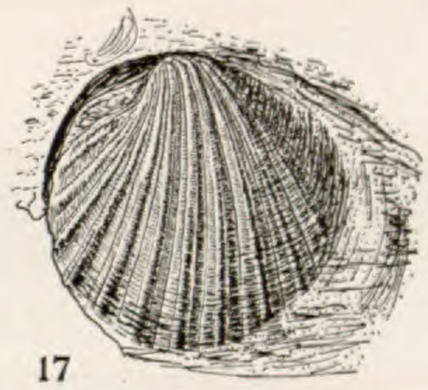

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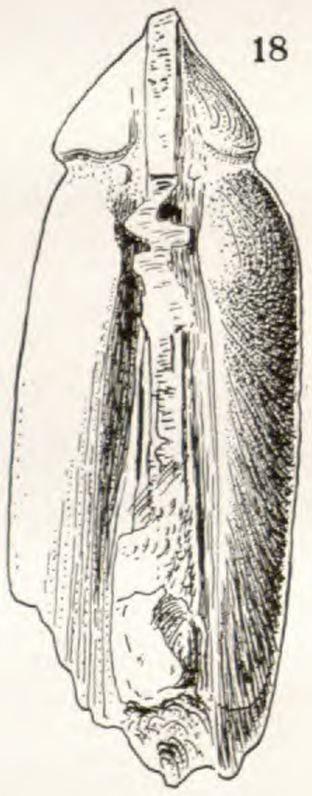

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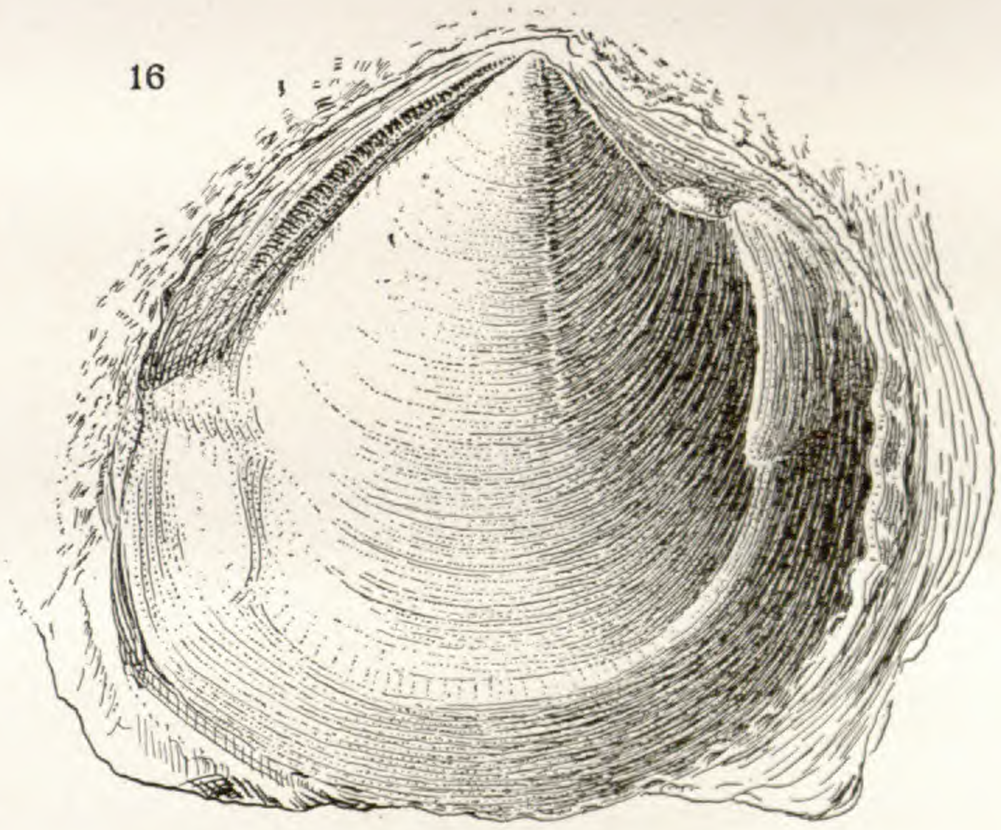

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PLATE IX.

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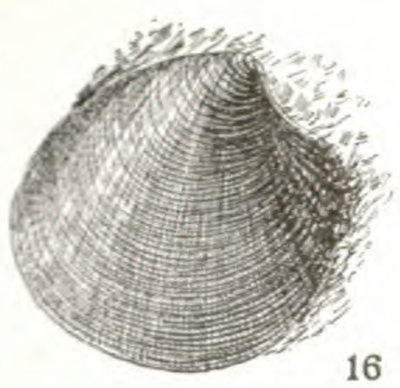

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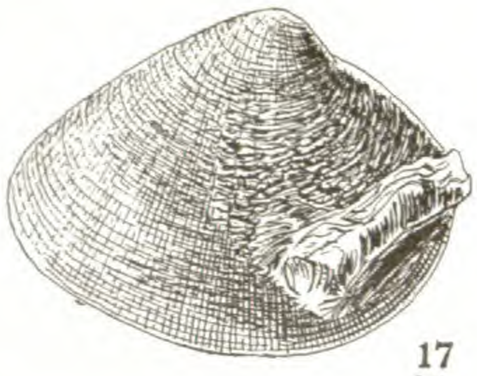

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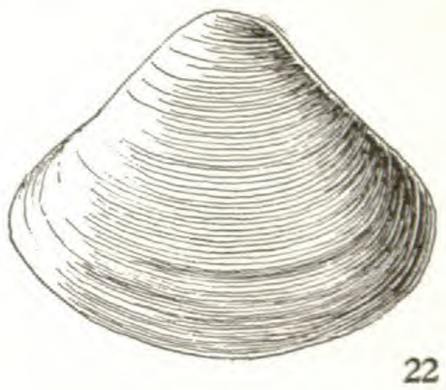

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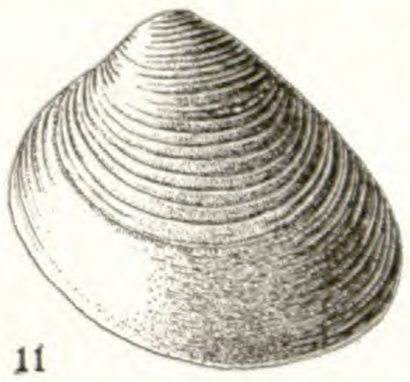

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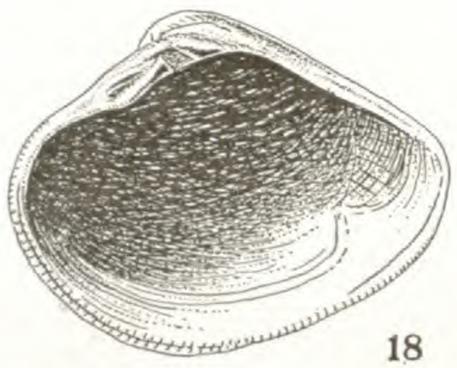

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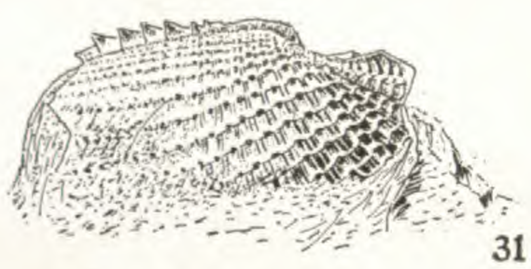

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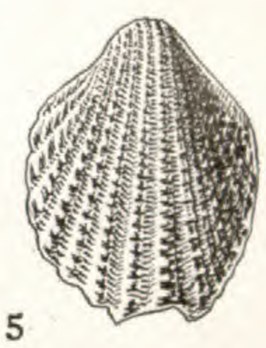

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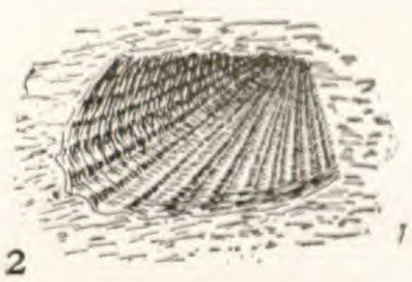

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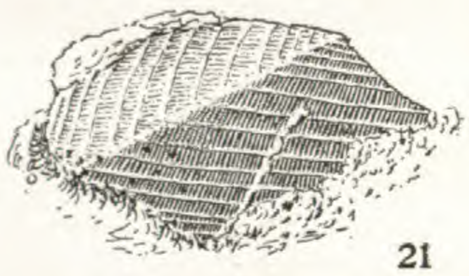

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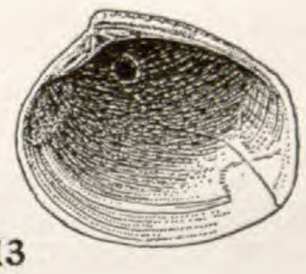

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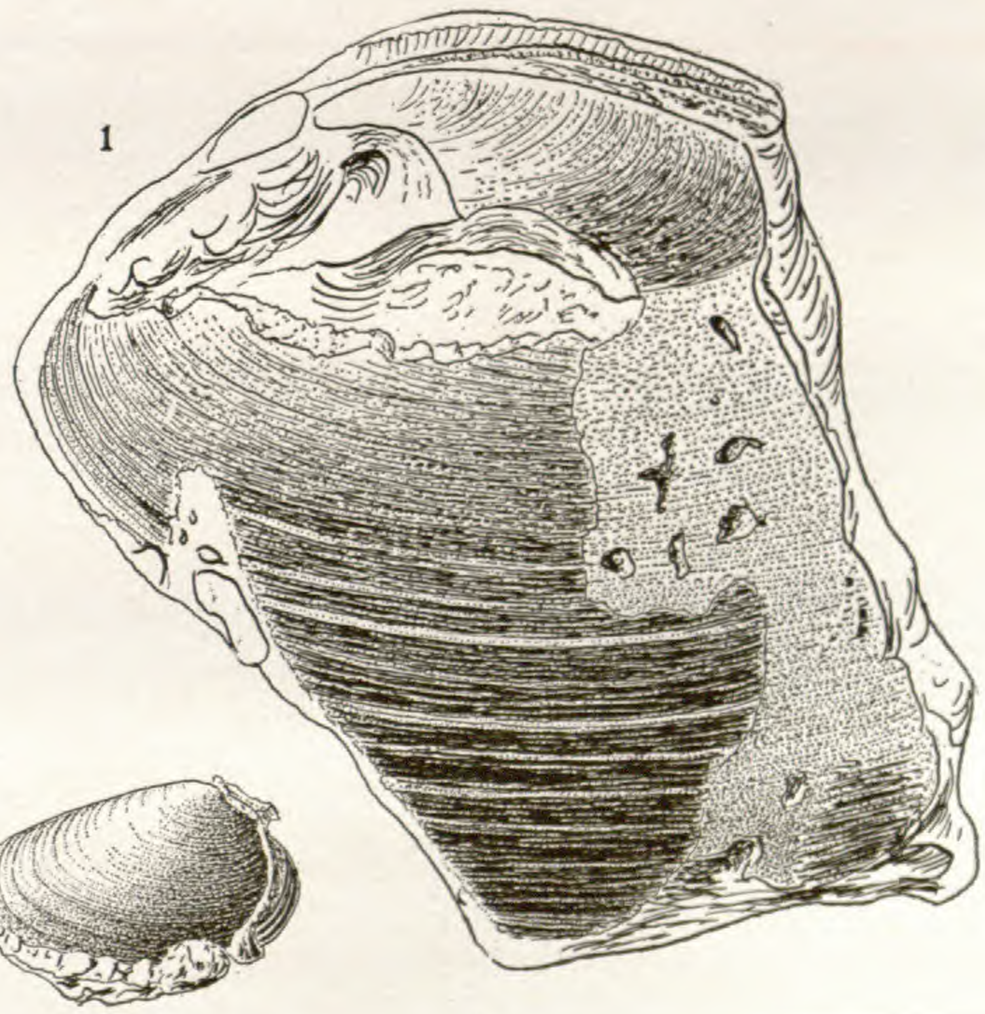

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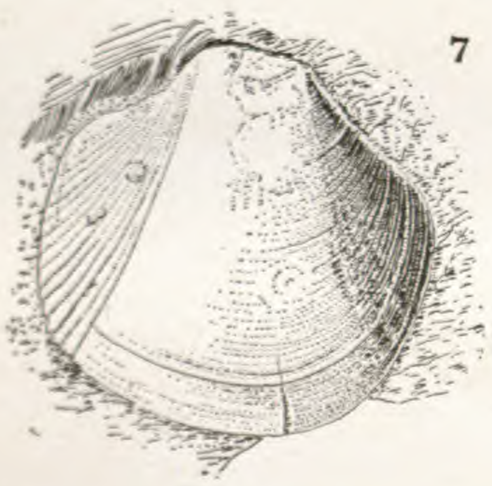

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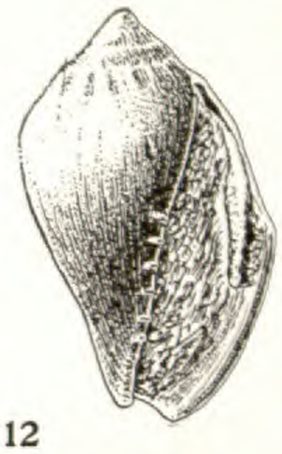

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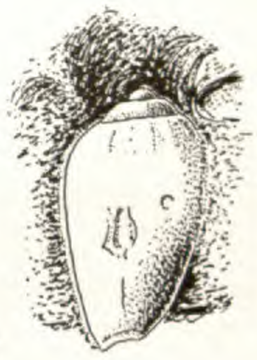

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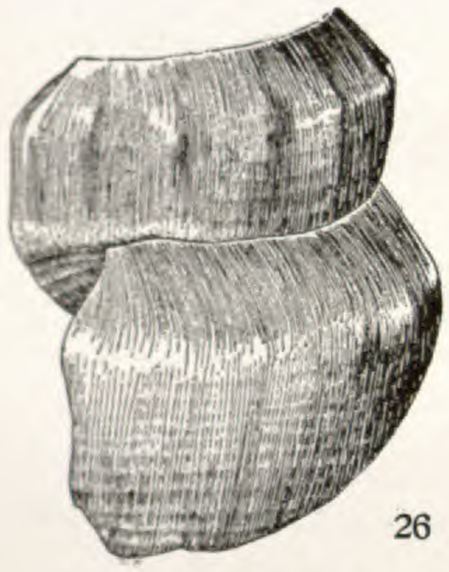

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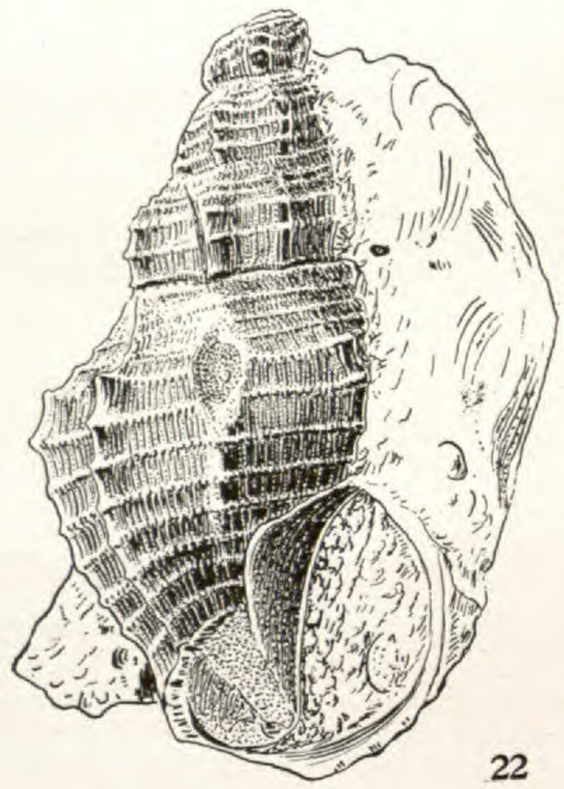

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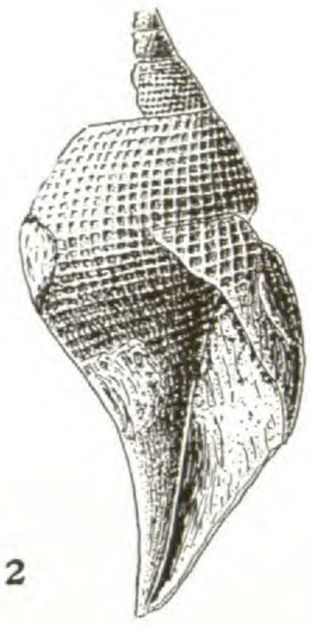

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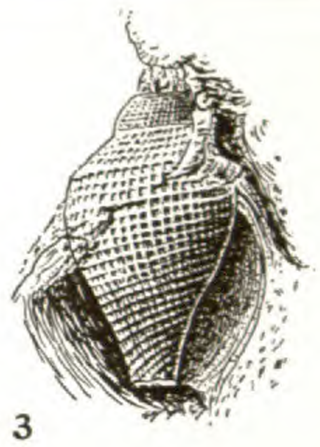

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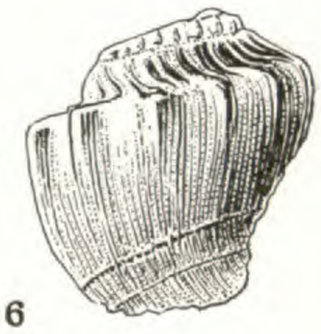

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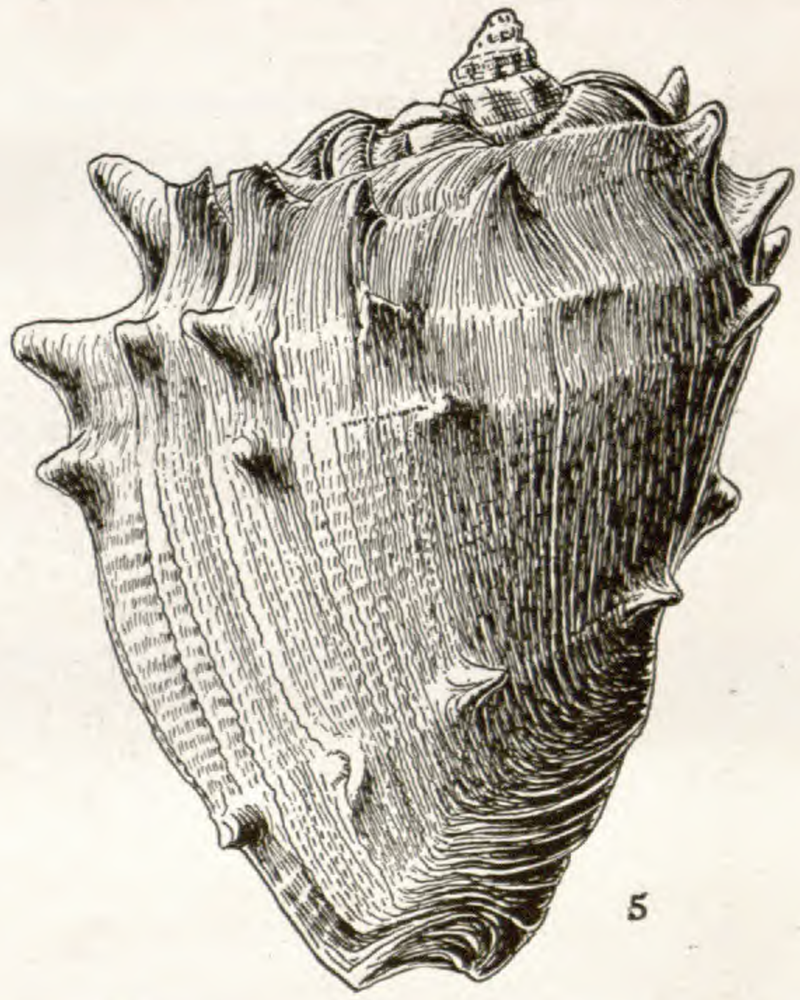

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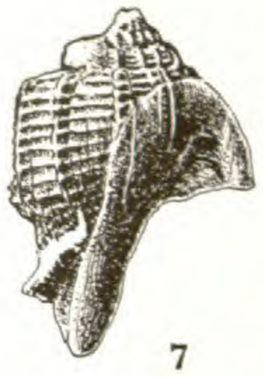

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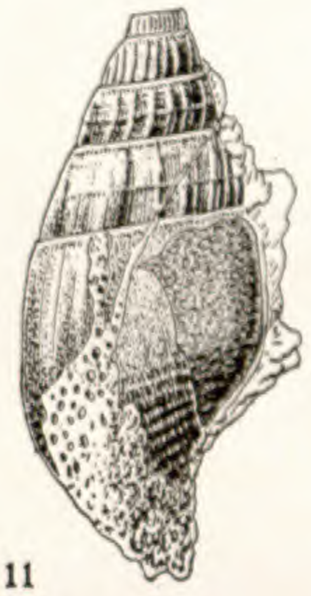

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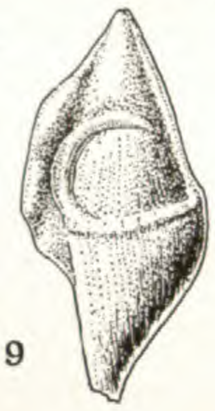

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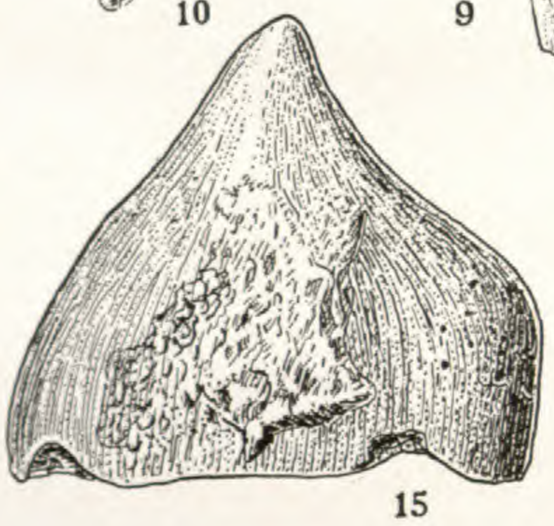

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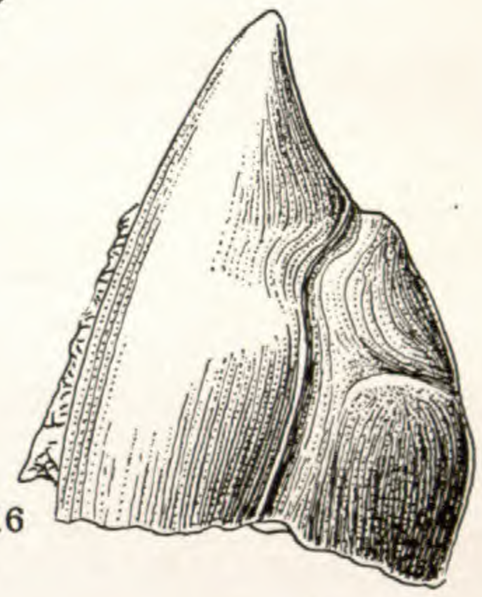

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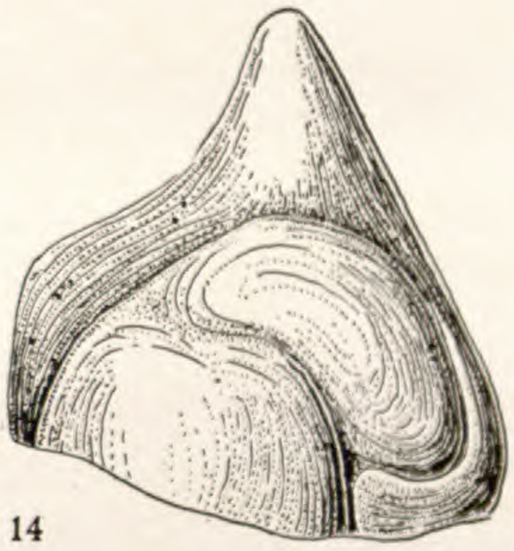

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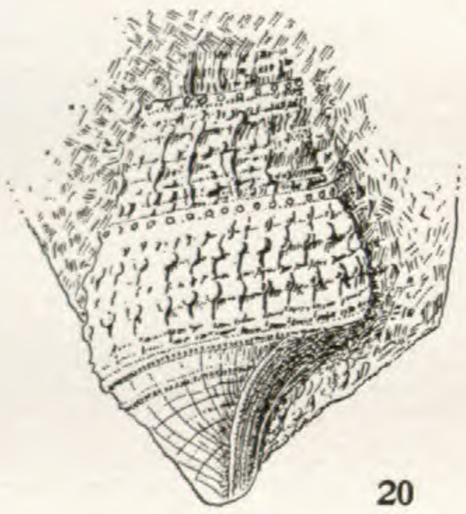

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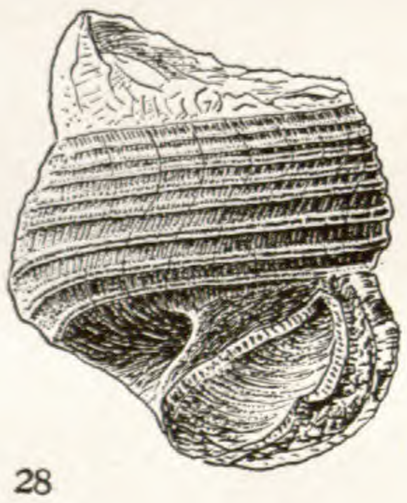

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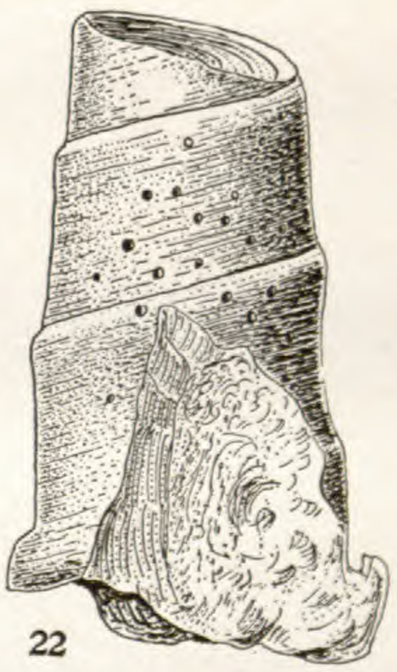

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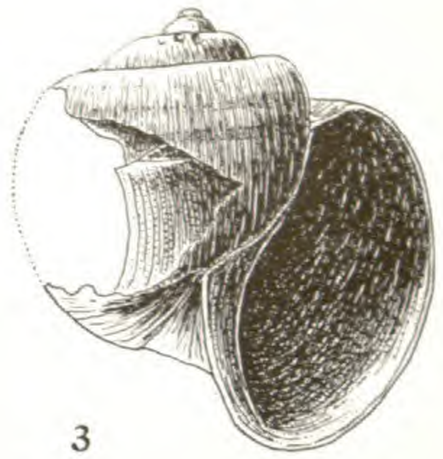

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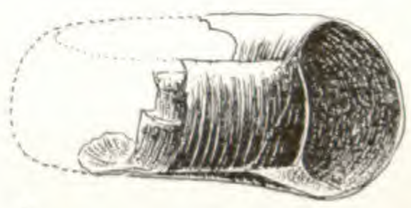

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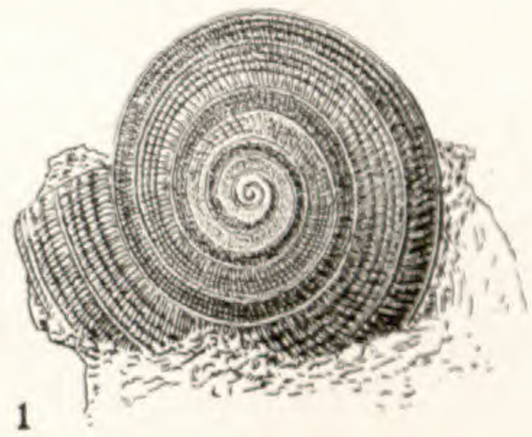

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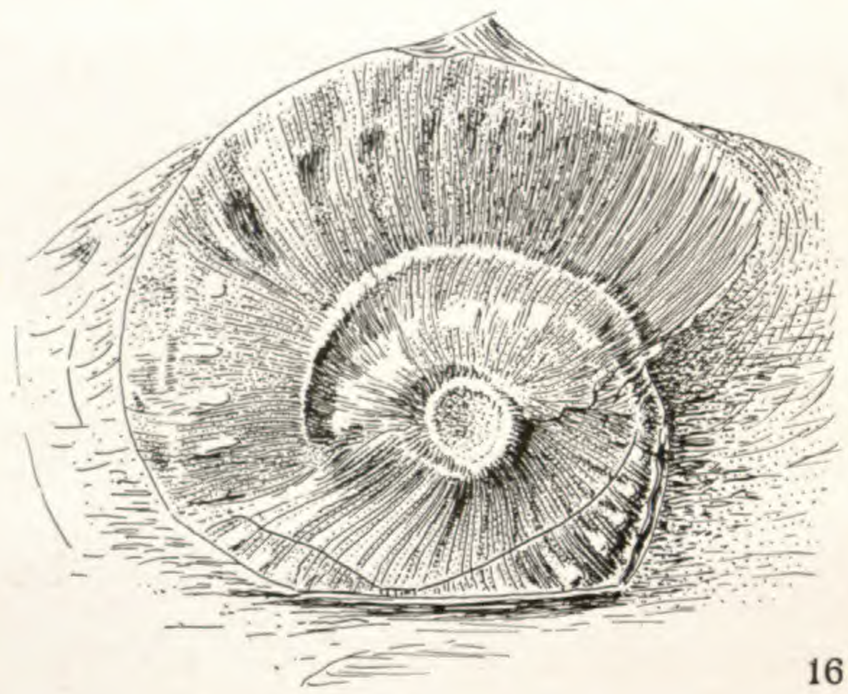

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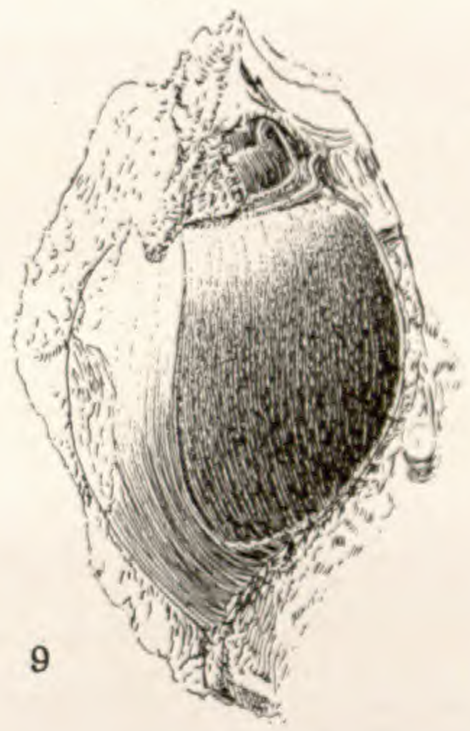

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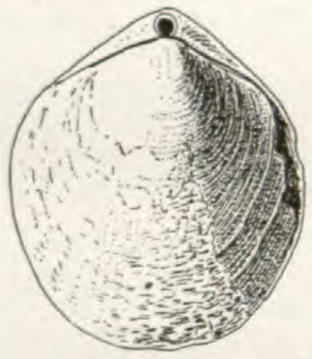

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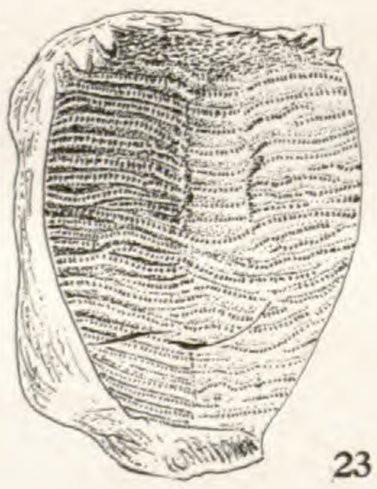

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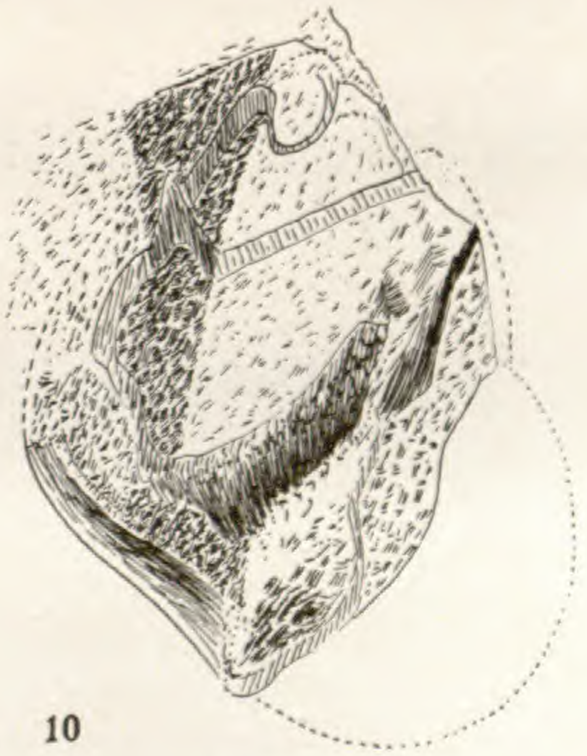

10

Early Adaptation in the Feeding Habits of Star-Fishes

BY

JOHN MASON CLARKE, A.M., LL.D., PH.D.

STATE GEOLOGIST AND DIRECTOR OF THE NEW YORK STATE MUSEUM

PLATES XIV, XV, XVI

PHILADELPHIA
1912

EARLY ADAPTATION IN THE FEEDING HABITS OF THE STAR-FISHES.

By John M. Clarke, Ph.D.

On several previous occasions the author has had opportunity to bring out rather interesting facts bearing on the very early history and primitive beginnings of certain organic activities which may fairly be characterized as bad habits; that is, "bad" from the point of view the observer naturally assumes as a member of the human community which catches the full cumulative effect of these habits as they have come down the ages with increased force and with roots sunk deep into the constitution of human society. I have hoped and still feel there is reason to hope that the close pursuit of these ancient evidences of adjustment into habits that still prevail among living organisms may lead to a better understanding of dependent conditions of life as they present themselves to us today.

The habits which I have been able to elucidate, or at least predicate for certain very ancient, wholly paleozoic creatures, are those of dependence resulting from adaptation—evidences of mutualism some of which date back even to the opening stages of the earliest Ordovician, with every indication of a previous existence in the Cambrian times. They are not alone conditions of symbiosis but early indications of the positive degeneration which commensalism invariably implies. Such arrangements were effected in the primitive faunas by the sessile worms which selected their hosts with variant taste among the florescent colonies of corals and sponges; wherever indeed there seemed to be a large and energetic working surface which would be to their feeding advantage. These associations are intimate and singular; and while these groups continue to associate in symbiotic condition to the present, in those most ancient days they assumed some peculiar expressions no longer recognized.

So with the barnacles and corals; with the corals upon themselves. The little wormlike *Myzostomum*, all of whose living species are parasitic on the crinoids, seems to have acquired this dependent habit back in these paleozoic days. Habits of boring by the sponges and algæ were so extremely common in the ancient faunas of the earth that the dead shells lying on the bottom of the old seas are found to be often punctured and riddled by the tubes of these little creatures.

Of rather momentous interest is the condition displayed by one case of genuine paleozoic parasitism—that of the gastropods upon the crinoids—an instance of abject dependence whose beginning we have reason to believe is well understood and is indeed most significant. We know that in the Ordovician days certain round-mouthed snails had acquired a loose association with the crinoids.

They were not in any way bound to it. These Cyclonemas hung around the anal orifice of the crinoids, nesting inside the arms of the creature and catching the waste for their own nourishment. In the Devonian we find here and there one of these coiled limpet-like shells attached to the crinoid in such a way as to cover the proct so that nothing escaped. At this time the habit was not general. In the early Carboniferous faunas this truly parasitic and dependent habit had become almost universal. Then the crinoids reached their maximum of numerical development and the snails, also at their maximum, began to surrender their independent life at a very young stage, passing almost their entire existence closely addicted to this easy life at another's cost.

This dependent habit came to end we believe with the great faunal and physical changes following paleozoic time. I think we are entitled to say that through altered physical conditions or freer distribution of food, nature here did rebound and this habit, degenerating and truly parasitic, was remedied without aid of the clergy. At all events, there is no evidence whatever of such mutual expressions between the crinoids and the great group of holostomatous snails represented by the *Capulidæ*, in the long periods of the Mesozoic and Tertiary. The present fauna does show certain affiliations, some of them clearly dependent, between living crinoids and some very degenerate snails, but as here different groups of gastropods are involved there seems no evident connection between the present and the ancient habit.

I have given a detailed account of these early symbiotic associations in a paper entitled "Beginnings of Dependent Life"[1] and in the presidential address before the Paleontological Society.[2]

An interest of a similar order pertains to the discovery which this occasion affords opportunity to describe. Recently we have uncovered in the Middle Devonian rocks of Hamilton age on the west side of the Hudson river in the town of Saugerties, N. Y., a layer of sandstone whose surface over the entire area which could be laid bare was dotted with starfish. The surface exposed was considerable, about 200 square feet, and from it were taken not less than 400 examples of the ancient starfish *Palæaster eucharis*, a species known before by only an occasional example. The uncovered rock was slightly tilted, as it lies in the region of Appalachian folding, and at both sides its continuity was destroyed by crush zones of faulting. So we have no expression for the enormous number of starfish that its original extent must have carried, but we may say that never before have the rocks afforded such a vast array of starfish in so limited a field. The Devonian shales at Bundenbach in the Rhineland produce these creatures, many and various, but not in such overwhelming numbers. One might stare at an oyster plantation on our northeast coast at low tide or turn his gaze upward at the Milky Way and find a comparable abundance of stars. Any other comparison fails.

[1] N. Y. State Museum. 4th Rep. Director, 1908, pp. 147–169, pl. 1–13.
[2] Science, February 24, 1911.

In association with these *Palæasters* are some of the invertebrate species usual to the fauna of the Hamilton stage; occasional brachiopods, a brittle star, of a few crinoids; but most in abundance are the clams of the period, large examples of *Grammysia* and *Pterinea* whose valves, sometimes separated and sometimes still held together by the preservation of the hinge ligament, are scattered very freely over the sandy bottom. It was the natural bottom for the development of the burrowing clams, a group to which *Grammysia* belongs, and doubtless quite as well suited to the more aviculoid or oyster-like *Pterinea*, which rested on or in the bottom with the lower valve of different form than the upper. There is little doubt that the field was the proper feeding ground and habitat of these clams and the evidence indicates that this being so, it was invaded by the starfish which congregated in these vast numbers in order to feed on the clams. Confirmatory of this is the fact that while elsewhere in this Devonian formation the pelecypods abound greatly where the deposits are sandy, the starfish has always proved of desultory occurrence and we had no conception of its profusion till the discovery of these deposits in Saugerties.

The starfish is today the menace of the oyster planter in the northeastern waters of our seaboard. Its voracious habits and its mode of attack on the oyster beds have been made the subject of extended study. The commercial loss to the industry by indulgence in these attacks has called for frequent appropriations of public money in the endeavor to find a way to check their depredations. When man, in setting his oyster plantation, spreads a special repast for a time-honored appetite, it need cause no wonder if the invitation is enthusiastically and multitudinously accepted. Thousands of bushels of starfish are yearly "mopped" out of even small oyster plantations and only eternal vigilance of this kind can ensure the survival of a profitable part of the oyster crop. The mode of attack and feeding by the starfish on its armored enemy, both oyster and clam, are well known now, since the experiments made by Schiemenz at the Naples Zoölogical Station and the observations by Mead at Woods Hole. Grasping the two valves with its flexible arms, some on one side and some on the other, and placing its mouth at the ventral edge of the valves, the starfish attaches itself by its tube feet or suckers and actually pulls apart the valves of the oyster or clam. That is, it accomplishes an act that a man could not without leverage, but it does this by tiring out its opponent. It pulls hard and long; its enemy pulls in the opposite direction harder but shorter; the muscular strain of holding the valves together is gradually overcome by the starfish, the tired clam slowly yields, the valves open and the incolant falls a victim to the eversible gorge of the starfish.

Among the specimens of the ancient starfish are many which lie in such relation to valves of *Grammysia* and *Pterinea* as to leave little doubt they were buried in the sediment while in the operation of feeding. The valves of one *Grammysia* are expanded and open flat out and a starfish lies inside one of them, its ambulacral and feeding surface exposed to the inner surface of the clam shell. In another the star seems to lie just outside the hinge of the expanded valve

again with its oral surface turned toward the shell. There are many examples of separated valves (one having been carried away or macerated) under which the starfish lies, face always against the interior of the shell. Indeed it has proved in many cases that a gentle tapping with the hammer over the surface of any of the clam shells will break down a thin film of rock and expose a starfish lying beneath, usually with its mouth up or towards the interior surface. Many stars may attack a single clam or oyster. That is often enough seen among the oyster beds and we find indications of similar habit in these fossils where a number of starfish are grouped about the clams as though relaxed by death from joint assault on the shell fish.

It is not to the shell fish alone that the star devotes its lickerish taste. It is omnivorous, but its attack on the clams has called into play a special adaptation of its procedure. It had the problem to reach the mail-clad animal within its armor and this problem it solved in the ages long gone.

This record of a venerable practice continued down to the present does not stand alone among ancient records of predatory habits. Such habits must of course be presumed, even though the vestigia fail. But it is not unusual to find among the mollusks of the Devonian and late Silurian faunas shells which have been bored through by the tooth ribbon of the carnivorous gastropods, the circular beveled holes remaining in shells of the victims with all the perfection of similar evidences of attack found on the shells along our beaches today.[3]

EXPLANATIONS OF PLATES XIV, XV, XVI.

PLATE XIV.

Part of a slab, natural size, with a number of associated clams and starfish. At the upper right are two Pterineas and one *Grammysia* with Palæasters clustered in and over them in attitudes which leave little doubt that they were engaged in their attacks when buried by the sediments.

Expanded valves of *Grammysia* with a single *Palæaster* in one of them, the oral face lying against the inside of the valve surface. Natural size.

PLATE XV.

Part of a large slab in natural size showing one starfish, face up, lying just within and beneath the hinge region of the expanded valves of *Grammysia*. Other Grammysias with associated starfish remains are visible in other parts of the plate.

PLATE XVI.

A slab of sandstone carrying twenty or more individuals of *Palæaster eucharis* Hall; an average example of the abundance of the starfish. Reduced.

[3] See *op. cit.* Rept. Direct. N. Y. State Mus., pl. 12, figs. 5–7.

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CLARKE: FEEDING OF STAR FISHES

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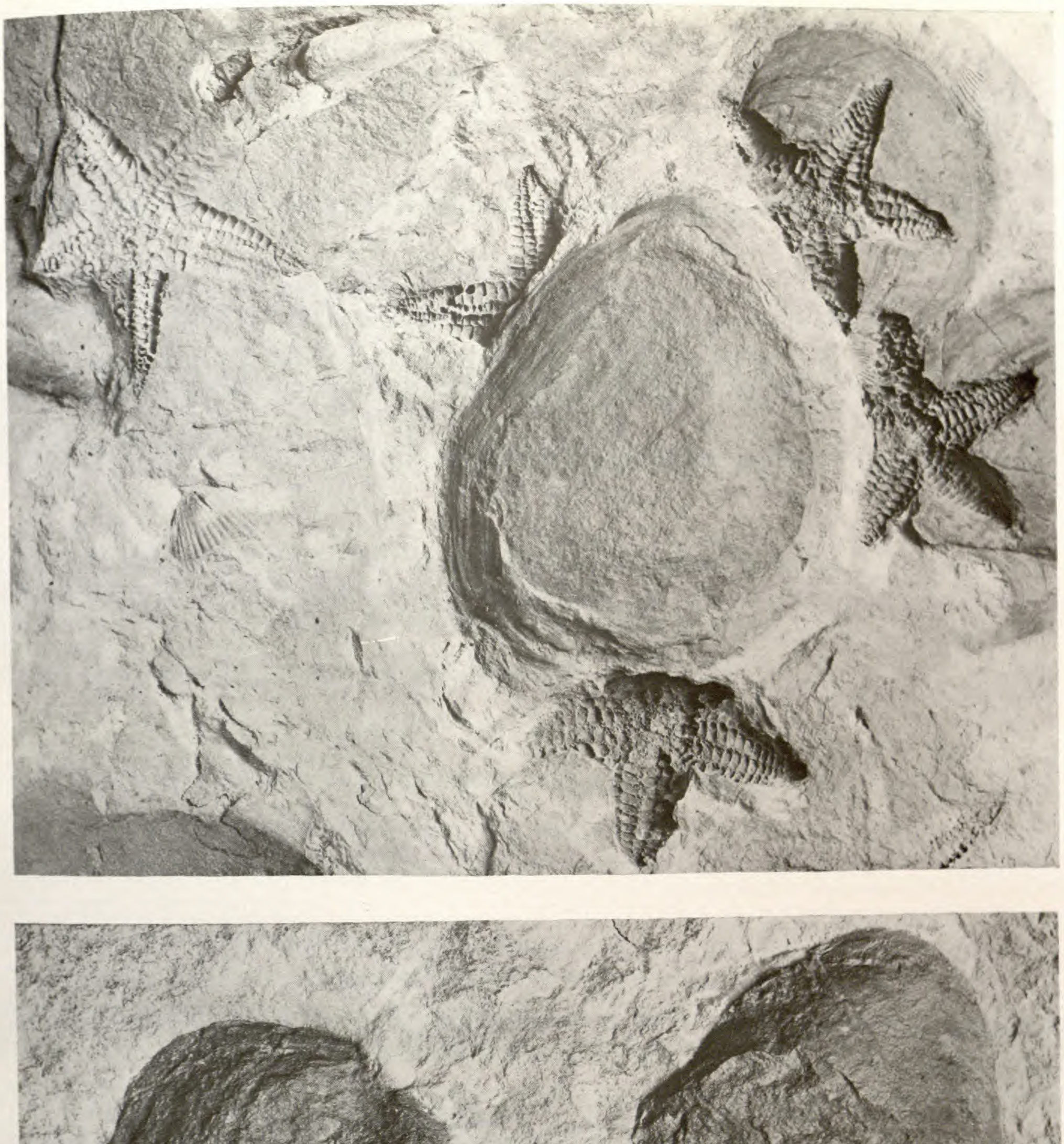

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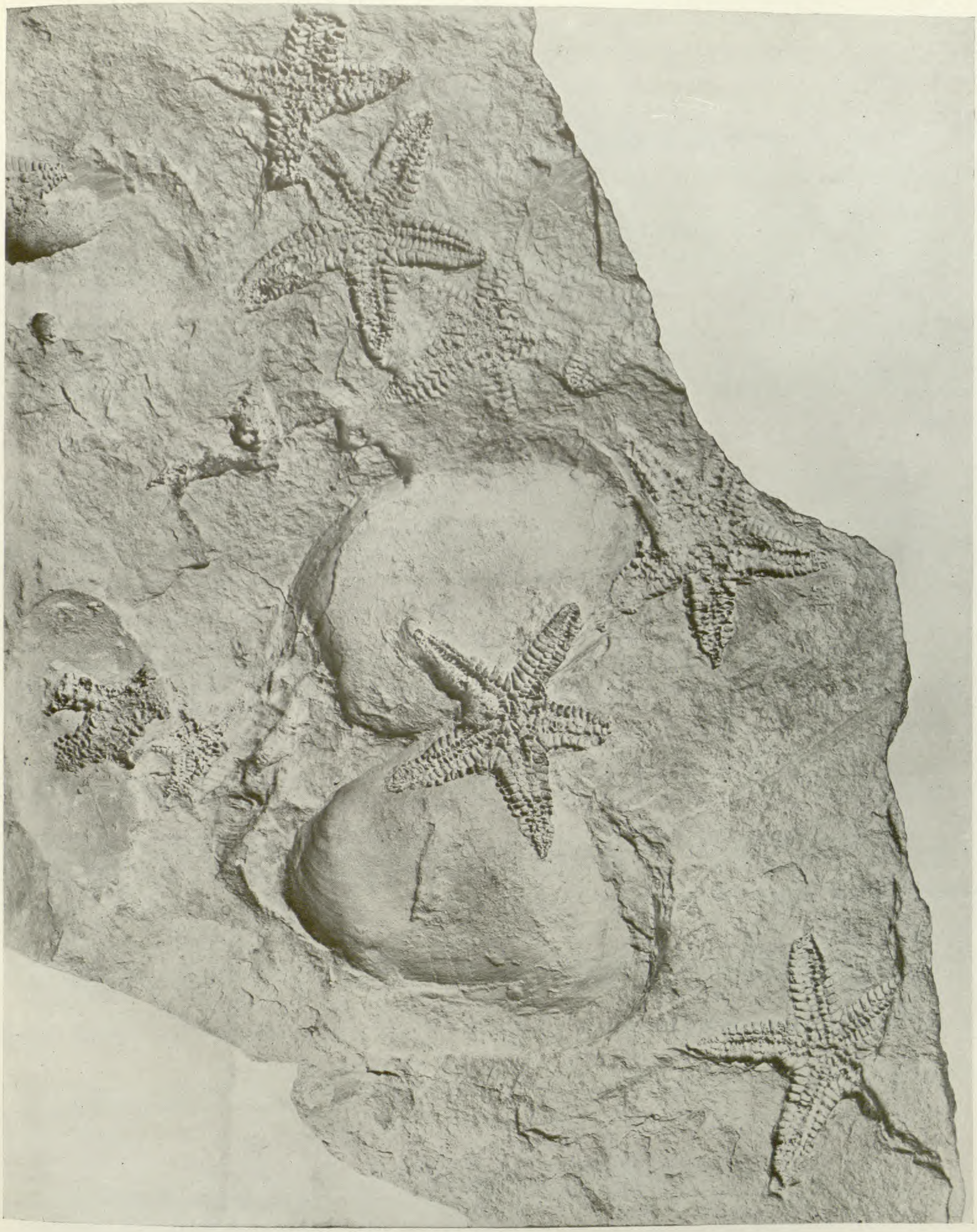

CLARKE: FEEDING OF STAR FISHES

Mimicry in Boreal American Rhopalocera

BY

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PHILADELPHIA

1912

MIMICRY IN BOREAL AMERICAN RHOPALOCERA.

By Henry Skinner, M.D., Sc.D.

Professor E. B. Poulton (4), the eminent student of the subject of mimicry, states that the butterfly fauna of North America probably affords the best field in which to take up this study. He also says the examples are sharp and striking and not too numerous. He considers these problems to possess the most profound significance in relation to the deepest questions by which the naturalist is confronted.

The literature of the subject has grown to large proportions and the subject has engaged the attention of many observers. Some of our American species of butterflies will be discussed in this paper from the standpoint of Batesian mimicry as defined by Poulton. This "is an advantageous deceptive resemblance borne by palatable or harmless species (the mimics) to others that are unpalatable or otherwise specially defended (the models)." Some of the species in the genus *Papilio* are said to be protected by their resemblance to certain other species in the same genus which in the larval condition feed on poisonous plants. Following Haase (8), Poulton has adopted the name *Pharmacophagus* for the so-called poisonous models.

Rothschild and Jordan (5) have divided the genus *Papilio* into three groups, called Aristolochia-swallowtails, Kite-swallowtails, and Fluted-swallowtails. In the Boreal American fauna there are three species belonging to the first group: *polydamas*, *devilliers*, and *philenor*. *Polydamas* is a West Indian species which has been recorded from the Indian river, Florida. *Devilliers* is a Cuban species that has also been taken at the lower extremity of Florida. *Philenor* is well distributed over the United States, except in the central district, from Colorado northward.

Two species belong to the second group: *marcellus* (*ajax*), and *marcellinus* (*sinon*). The remainder of our species in the genus fall among the fluted-swallowtails. Three species are said to be protected by mimicking *philenor* according to Poulton; they are *Papilio polyxenes asterius*, *P. troilus*, and *P. glaucus* (the dimorphic black female).

To logically prove this assumption it is necessary to show that birds are in the habit of eating butterflies and that some butterflies are poisonous or nauseous to them and others not. The deduction that certain species mimic others, according to the Batesian definition, would be difficult of proof, even if it be shown that the first two propositions are correct. Guy A. K. Marshall (3) in an interesting article entitled "Birds as a Factor in the Production of Mimetic Resemblances among Butterflies" gives a list of records for the Nearctic region and

most of his references are cited from Gentry (11). The observations made by Gentry were unreliable and probably nearly all fictitious. W. L. McAtee (2), an authority on this subject, says in reference to the work by Gentry, "but with regard to the bird food, it is certain that the only safe course is to regard them as almost entirely products of the author's imagination." Marshall has given numerous records from other parts of the world to sustain his contention.

Evidence of a negative character is not of overwhelming value but it certainly has its place, and should stimulate exact observation. Marshall states that "they (the opponents of the theory) unite in condemning the theories of mimicry on the ground that they involve too many assumptions for which there is no experimental evidence." In regard to the relations between birds and insects so far as this fauna is concerned, the case may be stated somewhat differently. Before the theory is accepted it will be necessary to have sufficient evidence to reasonably prove the hypotheses advanced by the advocates of Batesian and Mullerian mimicry. Packard (7) could only find records of four species of North American butterflies being eaten by birds: *Argynnis myrina*, *Vanessa milberti*, and *Pieris rapæ*. He says it is evident that for temperate North America and for Europe the evidence is entirely too slight to even suggest the theory; the attacks of birds are a negligible factor.

G. L. Bates (1) who spent six years investigating the stomach contents of birds of the South Cameroons, Africa, found Coleoptera in 213 stomachs and Orthoptera in 177, but no butterflies.

Dr. Philip P. Calvert, a distinguished neuropterist and careful field observer and collector, spent a year in Costa Rica and although he particularly looked for evidence of birds attacking butterflies, he did not see a single instance of it.

The literature on this subject so far as this particular fauna is concerned is meager. W. H. Edwards (10) says he believes that *Papilio turnus* was often destroyed by owls at night. Dr. Scudder mentions having seen a *troilus* which he inferred had been eaten by a bird.

W. G. Wright (6), a collector of great experience, says during twenty-five years' collecting on the Pacific coast of the United States he never saw but one attempt of a bird to catch a butterfly and the attempt ended in failure. I have asked the following well known entomologists and field workers whether they have ever seen birds attack and eat the bodies of butterflies: E. T. Cresson, E. T. Cresson, Jr., J. A. G. Rehn, Morgan Hebard, Frank Haimbach, H. A. Wenzel. They all replied in the negative. Hebard and Rehn have collected extensively in almost every part of the United States. Mr. Witmer Stone, a well known ornithologist, has not seen birds eat butterflies. The writer has collected American butterflies for forty-three years and has never seen a butterfly eaten by a bird.

For the present it therefore seems fair to assume that the evidence of mimicry in this respect is very far from being convincing.

Papilio philenor, the so-called pharmacophagus model, generally feeds, in the larval stage, on some species of *Aristolochia*.

Aristolochia serpentaria was formerly much used in human medicine for a variety of ailments and the theory has been built up on its supposed poisonous properties to man and theoretically on the fact that the butterfly imago would be nauseous to birds because its larva fed on this plant. There are ten species of *Aristolochia* found in the United States and three of them are from the vicinity of Philadelphia. *A. serpentaria* grows in shady woods, throughout the middle, southern, and western States. The root yields its active principle to either water or alcohol, and is said to contain one half of one per cent. of an essential oil, about as much resin, a little tannin, and a bitter principle. In ounce doses it deranges the digestion and may cause vomiting, colic, and diarrhea.

If it takes an ounce of the ground root to have an appreciable effect on the economy of *Homo sapiens* we can hardly call it an energetic poison and thereby assume that because the larva of the butterfly eats the leaves that the imago would be poisonous or nauseous. *Papilio philenor* also feeds on other species of *Aristolochia* that are not known to have any nauseous or poisonous properties. In the north, beyond the range of *A. serpentaria*, it feeds on *A. sipho*, the Dutchman's pipe. It also feeds on *Asarum canadense* and *Ipomœa bonei-nox*, a cultivated plant grown to a considerable extent for its shade and flowers. W. H. Edwards saw a female ovipositing on a species of *Polygonum* (*P. convolvulus?*), the black bindweed.

There is no evidence to prove that *P. philenor* is nauseous to birds. Neither does it follow that because it feeds on a plant slightly poisonous to man that it would have the same effect on birds. Mountain laurel, *Kalmia latifolia*, is fatal to man, sheep and some other animals, but is eaten with impunity by deer and partridges. Dr. Barton (12) says in his collections that the Indians sometimes use a decoction of the leaves for suicidal purposes. It is said that death has been occasioned by eating the flesh of partridges and pheasants which had been fed on the plant during the winter. Dr. N. Shoemaker has recorded two cases in the *North American Medical and Surgical Reporter*. Poisoning has resulted from eating a pheasant, in the craw of which laurel leaves were found. Here are recorded instances where a plant is poisonous to some animals, including man, and not poisonous to birds. To maintain that *philenor* is poisonous would require infinitely more evidence than we have at present. Cats are very fond of feeding on the imagos of *Protoparce quinquemaculata* and *carolina*. In this locality the larvæ feed on the leaves of the Jimson weed, *Datura stramonium*. This is highly poisonous to man and to other animals. We can at least infer from this that the imago of the moth does not necessarily have poisonous properties even if the larva does feed on a poisonous plant.

It is likely that birds feed on insects, other than butterflies, that have fed in the larval or imago conditions on plants that are very poisonous to man, as it is a well known fact that some species feed on the deadliest of plant life. Certain beetles eat aconite root with impunity. It would make an interesting series of experiments to learn whether the imagos of insects that have fed on vegetable

poisons in the larval condition, are poisonous or the contrary, when fed to birds and other animals. Professor Poulton declares that *Papilio philenor* has a strong disagreeable scent. This statement is evidently derived from observations made by W. H. Edwards to the same effect. Scudder (9) examined a living male, fresh from the chrysalis, carefully removed the androconia from the patch by scraping it with a knife, thereby bruising them and increasing the chance of odor, but was unable to perceive the very slightest, from the bruised scales, the fold, or the whole creature. The writer has caught a large number of these butterflies but never noticed any odor. We need more light on this point. It is a question that could be very readily settled where the species flies in abundance. Plateau and Wheeler have tasted so-called inedible or distasteful insects and found nothing particularly disagreeable about them. Poulton suggests that the question is not as to the palate of men but concerns the taste of birds, lizards, etc. This is eminently true but Poulton and others use a similar argument in the use of the word pharmacophagus. Neither does it follow that because some plant substances in large dosage will cause nausea and diarrhea in men that they will have the same action on birds after passing through the alimentary canal of the larva of a butterfly.

The three species said by Professor Poulton to mimic, have a great variety of food plants in the larval stage and doubtless among them are some that may be nauseous or poisonous to human beings and possibly more irritating to the stomach than *Aristolochia serpentaria*. The larva of *Papilio glaucus* feeds on species of the following genera and probably others not observed: *Ptelea, Prunus, Pirus, Cydonia, Cratægus, Styrax, Fraxinus, Syringa, Catalpa, Sassafras, Humulus, Carya, Quercus, Betula, Alnus, Salix*. Wild cherry appears to be the favorite in this locality. This plant has medicinal qualities and is used in affections of the bronchi in human beings. It is the black female of the species that is considered a mimic. The larva of *Papilio troilus*, another one of the mimics, feeds on *Benzoin, Magnolia, Xanthoxylum, Prunus, Pirus, Syringa, Sassafras, Ipomæa, Juniperus sabinaria*, a coniferous tree. The common food plants are sassafras and spice-bush. The third alleged mimic, *Papilio polyxenes asterius*, feeds on a great variety of Umbellifera. Scudder says it will probably eat any native or introduced umbelliferous plant. The larva has been found feeding on the following genera: *Daucus, Hydroctyle, Conium, Cicuta, Sium, Apium, Discopleura, Carum, Anethum, Fœniculum, Archangelica, Pastinaca, Tiedemannia*, and *Dictamnus fraxinella*, an introduced plant of the rue family.

It will be observed that this species in the larval stage sometimes feeds on the poison hemlock, *Conium maculatum*. This plant is very poisonous to human beings and fatalities have occurred owing to its resemblance to the harmless parsley. Why should *asterius* mimic *philenor* when some specimens of the species feed on a plant that is really poisonous to man while *philenor* feeds on a species doubtfully poisonous? The food plant that appears to be most frequented in this locality is the wild-carrot.

None of the butterflies mentioned by Packard as being attacked by birds feed on poisonous plants. We do have some butterflies that feed on plants that are called medicinal. *Terias nicippe* feeds on *Cassia marylandica*, wild senna. *Melitæa phaeton* larva feeds on *Chelone glabra*, balmony. *Papilio marcellus* (*ajax*) feeds on the paw-paw, *Asimina triloba*. Wild senna and balmony act as cathartics in the human economy and paw-paw is used by medical men of doubtful character. The principal enemies of the species of *Papilio* are not those that prey on the imago but those inimical to the egg, larva, and chrysalis. The eggs are destroyed by hymenopterous parasites, ants, spiders, crickets, and other insects. The larvæ are attacked by a number of hymenopterous and dipterous parasites and the chrysalids are destroyed by numerous enemies, such as squirrels, mice, lizards, birds.

There is little reason to believe that the stages of *philenor* are more immune to the attacks of enemies than the other species. Aaron found a colony of the larvæ on the moon vine. They were badly parasitized. The early stages have not been reared or studied as frequently as the other three species. While it is true that the butterfly is abundant in some places it is rare in the communities where there are entomologists. This is due to the fact that the food plants have become scarce, owing to being articles of commerce. In the northern States *Aristolochia sipho* is not a common plant but is only occasionally used as an ornamental vine. *Philenor* is rare in the vicinity of Philadelphia. I have seen the species abundant in the mountains of North Carolina, the specimens being unusually large. It is difficult to understand and interpret the laws of nature, and nature may do curious things, but if these species are subjected to so many risks in the three early stages why should they have a doubtful kind of protection in the imago form? Probably the answer would be that it is necessary to protect the female of the species as she has eggs to deposit and her death would mean the destruction of many individuals in an early stage of existence.

The three species, *glaucus*, *asterius*, and *troilus*, do bear a resemblance to *philenor* but this happens in any aggregation of species in a genus. They look alike to the human eye but birds may be able to differentiate them. They do not deceive the trained eye of the naturalist if he gets within a reasonable distance of them whilst they are on the wing.

The females of these species all differ more or less in appearance from their respective males. Scudder used the word antigeny to define these secondary sexual characters or differences. These differences occur in numerous species and it seems logical to consider that they are governed by a general law rather than that a few of them are caused by protective resemblance. The model species *philenor* is also antigenetic. Why should this be if antigeny is brought about by resemblance or natural selection? Surely we cannot account for the differences of appearance in the sexes of the model on the ground of protection. Professor Poulton says the three mimics, *glaucus*, *asterius*, and *troilus*, acting as secondary models, produced an effect on *Limenitis arthemis* and that the result of this

influence is seen in *Limenitis astyanax*, a secondary mimic of the three mimics of *philenor*. *Astyanax* is a black butterfly with a greenish or bluish luster and has the border of the wings marked with bluish or greenish spots. If the statement be true both sexes needed protection, as they are alike in appearance.

This idea could be carried still further by citing *Limenitis arizonensis* as a mimic. It is a species found in Arizona and northern Mexico. Poulton further declares that one of the most interesting elements in this complex mimetic system is the final appearance of a tertiary mimic of *astyanax*, the female of *Argynnis diana*. He need not have stopped here as the female of *nitocris* is also blue-black. In the greater number of species of *Argynnis* there is no antigeny and some observers hold that the antigenetic females of *diana* are ancestral forms (primitive). This would not be consistent with the theory of protective mimicry as the so-called mimics would be the more recent forms, as influenced by the models. The species in the genus *Argynnis* in North America that show marked sexual diversity are *diana*, *idalia*, *nokomis*, *leto*, *nitocris*, and *cybele*. In the female of *idalia* there is a double row of cream-colored spots on the secondary wings and in the male one of the rows of spots is red or tawny. The female *nokomis* is brown and buff and the females of *leto* are brown and buff. The female of *cybele* is generally normal (like the male), but in some instances is brown and buff, much resembling the female of *leto*.

The female of *nitocris*, as mentioned, is blue-black. I believe the antigeny in these species is due to a general law not understood. It does not seem consistent to pick out one species (*diana*) and say that its antigeny is due to tertiary mimicry. How can the dimorphism of the other species be explained? The theories in regard to the resemblance among our butterflies are very ingenious but the evidence or proof so far advanced seems inadequate. It will be necessary to show that butterflies are commonly used as food by birds; that the bodies of some species of butterflies are nauseous to birds; that the birds are unable to distinguish by sight between edible and non-edible species, if there are two classes, and that antigeny is brought about in all cases or at least in some by protective resemblance.

There is a striking resemblance between the butterflies *Limenitis archippus* (*disippus*) and *Anosia plexippus*. Professor Poulton speaks of *archippus* as the beautiful mimic of *A. plexippus*. The protective idea in this case is the same as in the so-called pharmacophagus butterfly, the imago of *plexippus* which is said to be repugnant to birds but the repugnance is not based on the idea of the butterfly feeding on a poisonous plant (*Asclepias*) in the larval stage.

There are two other species in the genus *Limenitis* that have been considered to be races or tophomorphs by some and valid species by others. They are *floridensis* Strecker and *obsoleta* (*hulsti*) Edw. The former is found in southern Florida and the latter in Arizona and Utah. *Floridensis* is considerably darker in color than *archippus*, and *obsoleta* is lighter in color than the latter. *Floridensis* is said to mimic *Anosia berenice*, and *obsoleta* is supposed to mimic *Anosia strigosa*.

Archippus is said to be derived from an ancestral form, *arthemis*. *Arthemis* and *weidemeyeri* have flourished prosperously in the struggle for existence, and it is difficult to understand why *archippus* should be so specially favored. The statements attempting to prove the evolution of *archippus* from an ancestral form (*arthemis*) seem to me to be very inconclusive.

How can we explain the color resemblance of *floridensis* to *berenice*, and *obsoleta* to *strigosa*?

The butterflies that have a range from north to south on the Atlantic slope, are generally larger and darker in color in the south. The Arctic form of *Papilio glaucus* is only about half the size of the Florida form. The Florida forms of *troilus* and *polyxenes* are also larger than in the north. In the Orthoptera the individuals of species having a northern and southern range are larger in the south and their colors are more decided. This is also true of birds and probably also in mammals. In the desert country (Utah and Arizona) in which *obsoleta* and *strigosa* fly, species having any considerable range are paler in color in the desert. This applies to birds and mammals also. In mammals the intense sunlight often causes a physical bleaching of the hair. Similar environmental conditions explain these color resemblances better than the hypothesis of mimicry.

American entomologists have not taken up the study of mimicry to any great extent and it is hoped that those persons interested in the subject on this side of the Atlantic will make accurate observations that will be of value in solving these questions. At present I take the view that there is not enough evidence to substantiate the hypothesis of mimicry in North American butterflies. The objections to the hypothesis are not to be ignored.

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The Petrographic Province of Neponset Valley, Massachusetts

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PHILADELPHIA
1912

THE PETROGRAPHIC PROVINCE OF NEPONSET VALLEY, MASSACHUSETTS.

By F. Bascom.

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INTRODUCTION.

While the igneous rocks of the Boston Basin have, from an early date, been the subject of considerable investigation and discussion, only recently have they been subjected to detailed petrographic and chemical examination. Such a study has been made of the Essex County Petrographic Province by Dr. Henry S. Washington[1] and of the Blue Hills Complex by the late Dr. Theodore G. White.[2] Adjoining the Blue Hills' province on the north and including the whole of Hyde Park, and portions of Canton, Dedham, Quincy, Milton, Mattapan, West Roxbury, and Dorchester townships, is a district of considerable topographic diversity drained by the Neponset River. Within this district, which is some three miles wide and ten miles long, are exposed a seemingly lawless assemblage of intrusive and effusive igneous rocks.

[1] Henry S. Washington, Journal of Geology, vol. VI, pp. 787–808, 1898; vol. VII, pp. 53–64, 105–121, 284–294, 463–482, 1899.

[2] Theodore G. White, Proceedings of the Boston Society of Natural History, vol. XXVIII, No. 6, pp. 117–156, 1897.

In 1899 a preliminary study was made by the writer[3] of the effusives of this basin. Since that time, owing to tunnelling and excavations, and through the invaluable assistance and courtesy of Professor W. O. Crosby, it has been possible to secure further material and to gather data on the hitherto obscure relations of the lava flows, the dikes, and the deep-seated granolitic rocks. It is the purpose of this paper to present these relations and to show how far they are sustained by the petrographic and chemical character of the igneous types.

The writer finds it a pleasure to express her profound obligations to Professor W. O. Crosby, at whose suggestion this study was undertaken, whose co-operation has rendered the investigation possible, and whose unequalled familiarity with this district has been at the service of the writer. Professor Crosby has afforded the writer opportunities to visit the district and to collect material and has liberally supplied her with excellent material collected by himself. The nine chemical analyses which appear in this paper were secured through Professor Crosby.

GENERAL GEOLOGY OF THE VALLEY.

The general geology of the region has been investigated by Professor Crosby[4] and is aside from the purpose of this paper. A brief statement of the stratigraphic and structural features of the valley will be pertinent in their bearing upon the age of the igneous material.

The prevailing rock is a conglomerate and the prevailing structure is anticlinal. Along the northern margin of the valley the conglomerate dips to the north under a slate and along the southern margin the dips are to the south and the conglomerate passes again under the slate; this structure is complicated by several sharp synclines and numerous faults. In the central and western part of the valley erosion has uncovered the igneous rocks: the acid volcanics and plutonics are the floor upon which the conglomerate rests, while the more basic volcanics occur as intrusives and as flows interbedded with the conglomerate; there are three flows of non-porphyritic basic lava and one of a porphyry of intermediate composition. The conglomerate is of Carboniferous age; the acid igneous material is then pre-Carboniferous and the basic igneous material Carboniferous.

The igneous rocks are exposed in four considerable areas with many small outlying bodies. The relations of the acid igneous types are best seen in the Stony Brook Reservation and adjacent territory, which, in a general way, is a repetition on a small scale of the Blue Hills Complex. The oldest formation exposed is a normal, medium to coarse-grained, arfvedsonite granite; this granite undoubtedly constitutes the main body of a batholite formed in and beneath Cambrian strata, of which a few remnants remain uneroded. The contact zone developed on the periphery of this batholite consists, as in the Blue Hills, in part of a fine-grained

[3] Volcanics of Neponset Valley, Bulletin of the Geol. Soc. Amer., vol. II, pp. 115–126, 1900.

[4] W. O. Crosby, Genetic and Structural Relations of the Lower Neponset Valley, Massachusetts. Amer. Geol., vol. 36, 1905, pp. 34–47, 69–83. Tech. Quart., vol. XVIII, no. 4, 1905, pp. 386–409.

granite and in part of rhyolite porphyry; these two types, grading into each other and into the normal granite, which they are clearly seen to cover, are alike in the absence of all fluidal, spherulitic, or brecciated textures.

Cutting both granite and peripheral zones is a remarkable dike, 100 feet wide, which is alternately rhyolite porphyry and granite porphyry; the porphyritic character, which is always conspicuous, makes the dike easily recognizable; it is one of a series and the only one of which detailed study was made; it is essentially identical in composition with the granite and the peculiar textural variations which it shows may be owing to varying depth of solidification. It is younger than the rhyolite porphyry which it penetrates and older than the rhyolite dikes which are found cutting it.

Also cutting the normal granite and both types of the contact zones, are very numerous and mostly irregular dikes of rhyolite, which, varying in width from an inch or less to fifty feet or more, are usually, but obscurely, porphyritic and often show fluxion lines especially near their margins; this fluidal banding, always parallel to the bounding walls, in one dike, three to four feet wide and perfectly banded throughout, is in strict conformity to highly irregular walls of the coarse normal granite. It is believed that they are contemporaneous with the acid volcanics to which some of them may well enough have been channels of supply, an hypothesis confirmed by a petrographic and chemical comparison. Both the volcanics and the dikes are clearly much younger than the granite batholite and its contact zone, which they overlie and penetrate; the cover of the batholite, Cambrian slate, must have been completely eroded before the lavas were effused.

Professor Crosby believes that he has located three necks or vents. The largest and least questionable of the three occupies an area, bounded by Grove, Center, Stimson, and Washington streets in West Roxbury, roughly oval in form, and some 1500 by 3500 feet in dimensions. The mass, consisting chiefly of brecciated rhyolite and a few included riders of slate, is sharply defined from the surrounding microgranite and normal granite, penetrating which are radiating rhyolitic dikes, and above which scattered in irregular patches are the remnants of rhyolite flows. These lavas exhibit unmistakably effusive characteristics and may always be distinguished by them from the rhyolite facies of the batholite. Two other necks—Bold Knob and Grew's Wood necks—are located in Hyde Park.

Of more recent age than the rhyolitic lavas and dikes are andesitic dikes which bear a strong resemblance to the andesitic flows also exposed in this district, and which, with the rhyolitic flows, are the subject of an earlier investigation.[1] These dikes, which are irregular and range in width from an inch or less to twenty feet or more, are thought to be related to the andesitic flows, which are interbedded with carboniferous conglomerate, in the same way that the rhyolite dikes are related to the rhyolitic flows.

Among the volcanics definitely known to be of Carboniferous age are patches of lava of a trachytic composition; the relation in age of these lavas and the

[1] Bascom, op. cit., pp. 122–125.

andesitic lavas has not been worked out; both are younger than the rhyolitic lavas.

Finally, completing the igneous series, though of a much later age and exhibiting no relation in composition or origin to any of the other rocks, there are two systems of diabase dikes.

PETROGRAPHY.

Plutonic Igneous Rocks.

Granite.—Fresh specimens of the normal granite of the batholith were obtained from quarries at the corner of Center and Grove Streets, between Center and Cottage Streets, southwest of Cottage Street, and, finally, on Cottage Street near Washington Street.

The rock is rather coarse-grained and permits one to recognize in the hand specimen idiomorphic pink orthoclases, which sometimes occur in crystals over 3 cm. in length, light green plagioclases, conspicuous allotriomorphic quartzes and a dark green fibrous or sometimes granular constituent which seems to be a chloritized amphibole.

The feldspars are plainly more or less epidotized and slickensided joint surfaces often show a coating of epidote. The leucocratic constituents predominate, constituting about nine-tenths of the rock and giving to the granite its prevailing light tone.

The constituents noted in the hand specimens appear in the slides and in addition, magnetite, apatite, titanite, and allanite. *Feldspar* is the most abundant component, constituting at least two-thirds of the rock; it appears in two species,—orthoclase and albite, of which albite is about twice as abundant as orthoclase; orthoclase, which is often perthitic, may be distinguished by a freedom from the epidotization characteristic of the plagioclase as well as by its extinction angle. The extinction angles on the plagioclase are those of *albite* with the composition of Ab_8An_1; the albite is clouded with minute grains and aggregates of grains of epidote, to which is owing the green color of the feldspar in the hand specimen; usually the epidote grains are uniformly but thinly distributed through the mineral, but in some instances a marginal and presumably more acid zone of the crystal is comparatively free from epidotization.

Quartz occurs in considerable allotriomorphic areas, constituting about one-fourth of the rock and is of the usual granitic character; it is often cracked and these cracks, filled with hematite globulites, give a brilliant rose color to the quartz in the hand specimen.

Chlorite, studded with magnetite grains and including lenses of epidote, represents some completely altered ferromagnesian lime silicate; the form and cleavage of this constituent in some cases suggest a member of the amphibole group and in other cases longitudinal sections of biotite; rarely original amphibole shows in scanty scales possessing the pleochroism of arfvedsonite; these melanocratic constituents compose but a small fraction of the rock.

The rock texture is granolitic; pressure effects are not conspicuous nor is microcline present in the material studied.

Chemical Composition.

All the analyses of the Neponset valley igneous rocks were made in the chemical laboratory of the Massachusetts Institute of Technology. Typical fresh specimens of the normal granite were selected for chemical analyses from the quarries represented by the slides.

With the analyses of the Neponset granite have been tabulated for comparative purposes two analyses of granite from adjacent districts; a hornblende-granite from Essex County, and a riebeckite-granite from the Blue Hills complex.

	I.	II.	III.
SiO_2	71.34	77.61	73.93
Al_2O_3	13.97	11.94	12.29
Fe_2O_3	1.95	0.55	2.91
FeO	1.00	0.87	1.55
MgO	0.62	trace	0.04
CaO	1.63	0.31	0.31
Na_2O	4.83	3.80	4.66
K_2O	3.89	4.98	4.63
H_2O+	0.80	0.23	0.41
H_2O-	0.09	trace	....
TiO_2	0.43	0.25	0.18
MnO	trace	trace	trace
	100.55	100.54	100.91

I. Arfvedsonite-granite, Stony Brook Reservation. Wm. T. Hall, analyst.
II. Hornblende-granite, Rockport, Cape Ann. H. S. Washington, analyst.
III. Riebeckite-granite, Hardwick Quarry, Quincy, Blue Hill. H. S. Washington, analyst.

NORMS.

	I.a.		II.a.[6]		III.a.[6]
Quartz	24.72		35.4		28.9
Orthoclase	22.80		29.5		27.2
Albite	40.87		32.0		37.2
Anorthite	5.00		0.8	Acmite	1.8
Wollastonite	1.28	Diopside	0.8		1.5
Enstatite	1.60	Hypersthene	0.2		0.4
Magnetite	2.09		0.9		3.2
Ilmenite	0.76		0.5		
Hematite	0.48				

I. Arfvedsonite-biotite-grano-lassenose.
II. Hornblende-grano-liparose.
III. Riebeckite-grano-liparose.

The Neponset Valley granite differs from the adjacent Quincy granite and from the Rockport granite chiefly in its higher percentage of lime; the Quincy granite has no anorthite molecule, is peralkalic and sodipotassic, in which it closely resembles the Rockport granite. The Neponset granite is domalcalic

[6] H. S. Washington, Professional Paper No. 14, U. S. Geol. Survey, 1903, p. 144.

and dosodic; the higher percentage of lime is associated with epidotization; this and the presence of biotite should distinguish the Neponset granite in the hand specimen. Since plagioclase feldspar predominates over orthoclase, the Neponset granite is of the quartz-monzonite type.

MODES.

	I.b.	II.b.	III.b.
Quartz	23.2	35.5	30.2
Orthoclase	22.9	28.2	27.2
Albite molecule	40.5	32.0	27.7
Anorthite molecule	5.3	0.5	...
Biotite	3.8	1.3	...
Hornblende	...	2.0	...
Arfvedsonite	3.1	...	...
Riebeckite	...	...	12.3
Glaucophane	...	...	2.0
Magnetite	1.2	...	...
Accessories	...	0.5	0.6
	100.0	100.0	100.0

Micro-granite.—As has been stated the normal granite grades upward into a fine-grained granite.

Specimens of this facies of the batholith were obtained on the west and east sides of Washington Street north of Grove Street, on the railroad one-half mile from Spring Street, in a quarry on Cottage Street near Washington Street, and in the northeastern part of Stony Brook Reservation.

The material is uniformly fine-grained merging into a microgranite; it is light colored, usually of a pinkish cast of color but may be greenish; feldspar and quartz and a very subordinate melanocratic constituent, which seems to be chlorite, may be distinguished in the hand specimen.

The slides show the same constituents as those exhibited by the normal granite, but the textures vary from the typical granolitic texture. Again there are prominently present two species of feldspar; perthitic *orthoclase*, *albite* (Ab) and *albite* of the approximate composition $Ab_{12}An_1$; and in addition a little of a more basic plagioclase, *oligoclase* (Ab_6An_1 to Ab_5An_1), and scanty microcline. Granular epidote is frequently developed in the feldspar and when very abundant gives a greenish tone to the rock; sericite is also an alteration product of the feldspar. *Quartz* is more abundant in proportion to the feldspar than in the normal granite with a ratio of 33 to 63, and is often full of linearly arranged inclusions both solid and liquid; the latter show a movable bubble which can readily be discerned with a high power.

The melanocratic constituents constitute not more than 4 per cent. of the rock; scanty magnetite is in many of the slides the only melanocratic constituent; when found other melanocratic constituents are represented as in the normal granite by a green, pleochroic, faintly polarizing chlorite associated with abundant magnetite; scanty blades of a mineral of the amphibole group, exhibiting a some-

what faint pleochroism—a = bluish green, b = pale blue, c = pale greenish yellow, a>b>c with extinction 14°—, may also be present. In the fine-grained material the prevailing fabric is micro-graphic; quartz and plagioclase feldspar are intergrown or quartz and perthitic orthoclase. In the microgranitic material the typical fabric is the orthophyric though, where perthite is the prevailing feldspar, there is a tendency toward the porphyritic fabric.

Chemical Composition.

The material for analysis was made up from the same fresh material which furnished the slides.

FINE-GRAINED GRANITE OR MICRO-GRANITE OF NEPONSET VALLEY.

		NORM.		MODE.	
SiO_2	76.52	Quartz	30.48	Quartz	32.2
Al_2O_3	12.30	Orthoclase	27.24	Orthoclase	27.3
Fe_2O_3	0.70	Albite	37.73	Albite ($Ab_{12}An_1$)	9.5
FeO	0.56	Acmite	1.85	Albite molecule	25.3
MgO	0.16	Sodium metasilicate	0.98	Anorthite molecule	1.6
CaO	0.31	Diopside	1.43	Arfvedsonite	3.7
Na_2O	5.19	Hypersthene	0.60	Magnetite	.3
K_2O	4.58	Ilmenite	0.15		100.0
H_2O +	0.41		100.46		
H_2O −	0.11				
CO_2					
TiO_2	0.12				
P_2O_5					
MnO	trace				
Total	100.96				

Wm. T. Hall, analyst.

The rock is a grani-liparose.

The chemical relations of the fine-grained and the normal granites will be discussed after the rhyolitic facies has been described.

Rhyolite.—The extreme peripheral facies of the granite batholith—that into which the micro-granite merges upward—is a massive rhyolitic porphyry exhibiting somewhat conspicuous phenocrysts of quartz and feldspar, and in some instances melanocratic phenocrysts.

Specimens of this peripheral type were obtained from the Summit, from Turtle Pond, and southwest of Turtle Pond Road, Stony Brook Reservation.

The color of the rock is purple or dark green. It is distinguished from the rhyolite that occurs in dikes and flows by a less fine-grained texture and by the absence of effusive characters: the effusive rhyolite exhibits a cryptocrystalline, jasper-like texture and breaks with very sharp edges; it also possesses all the fabrics characteristic of acid lavas, and is associated with pyroclastics: the peripheral rhyolite, while aphanitic, is scarcely cryptocrystalline and exhibits neither fluxion, spherulitic nor amygdaloidal fabrics.

The constituents are those of the granite massif. Quartz occurs abundantly as phenocrysts and is crowded with fluid and solid inclusions. Feldspar is represented by two species, *orthoclase* and *oligoclase*, which are present in approxi-

mately the same proportions and together constitute about 60 per cent. of the rock; extinctions on the phenocrysts indicate oligoclase of about the composition Ab_5An_1: sericite, chlorite and epidote are secondary products of the feldspar. The groundmass is a fine-grained, granular mosaic of quartz and feldspar, in which the latter mineral predominates.

The melanocratic constituent, constituting less than 10 per cent. of the rock, is represented by green blades of a pleochroic chlorite with iron oxide marking the basal cleavage of the original mineral and lenses of epidote lying parallel to this cleavage. Magnetite and apatite are accessory constituents, and chlorite, epidote, iron oxides, sericite, and calcite are the secondary products.

Chemical Composition.

The material for this analysis was obtained from the localities represented by the slides examined, and was of an exceptionally fresh character.

RHYOLITIC FACIES OF GRANITE, STONY BROOK RESERVATION.

SiO_2	71.63
Al_2O_3	13.71
Fe_2O_3	2.09
FeO	1.76
MgO	0.19
CaO	1.31
Na_2O	3.24
K_2O	4.49
H_2O+	0.51
H_2O-	0.08
CO_2	0.41
TiO_2	0.34
P_2O_5	trace
MnO	small amount (less than 0.10)
S	small amount
Total	99.76

Wm. T. Hall, analyst.

NORM.

Quartz	32.16
Orthoclase	26.69
Albite	27.25
Anorthite	6.39
Corundum	1.12
Hypersthene	1.42
Magnetite	3.02
Ilmenite	.61
	98.66

MODE.

Quartz		30.5
Orthoclase		26.5
Oligoclase	albite	27.7
	anorthite	6.5
Biotite		6.8
Magnetite		2.0
		100.0

The rhyolite differs from both the normal granite and the fine-grained granite in showing no indication of an amphibole constituent. The chloritized ferromagnesian constituent possesses the form and cleavage of biotite and is bent in a manner characteristic of that mineral; the analysis sustains these indications of the character of the original mineral.

The rhyolite is a phyro-toscanose.

COMPARISON OF CHEMICAL COMPOSITION OF GRANITE AND PERIPHERAL FACIES.

	I.	II.	III.
SiO_2	71.34	76.52	71.63
Al_2O_3	13.97	12.30	13.71
Fe_2O_3	1.95	0.70	2.09
FeO	1.00	0.56	1.76
MgO	0.62	0.16	0.19
CaO	1.63	0.31	1.31
Na_2O	4.83	5.19	3.24
K_2O	3.89	4.58	4.49
H_2O+	0.80	0.41	0.51
H_2O-	0.09	0.11	0.08
CO_2			
TiO_2	0.43	0.12	0.41
P_2O_5			0.34
MnO	trace	trace	trace, less than 0.10
	100.55	100.96	99.76

I. Normal granite—Neponset Valley.
II. Fine-grained granite or micro-granite—Neponset Valley.
III. Rhyolitic facies of granite—Neponset Valley.

NORMS.

	I.b.		II.b.		III.b.
Quartz	24.72		30.48		32.16
Orthoclase	22.80		27.24		26.69
Albite	40.87		37.73		27.25
Anorthite	5.00	Acmite	1.85	Anorthite	6.39
Wollastonite	1.28	Sodium metasilicate	0.98	Corundum	1.12
Enstatite	1.60	Diopside	1.43		
Magnetite	2.09	Hypersthene	0.60		1.42
Ilmenite	0.76		0.15		0.61
Hematite	0.48			Magnetite	1.42
	99.60		100.46		97.06

I.b. Arfvedsonite-biotite-grano-lassenose. Class 1, order 4, rang 2, subrang 4.
II.b. Grani-liparose. Class 1, order 4, rang 1, subrang 3.
III.b. Phyro-toscanose. Class 1, order 4, rang 2, subrang 3.

MODE.

	I.a.	II.a.	III.a.
Quartz	23.22	32.31	30.5
Orthoclase	22.85	27.33	26.5
Albite	40.51	34.74	27.7
Anorthite	5.27	1.64	6.5
Biotite	3.84		6.8
Arfvedsonite	3.11	3.70	
Magnetite	1.20	.28	2.0
	100.00	100.00	100.00

I.a. Normal granite, Neponset Valley.
II.a. Fine-grained granite or micro-granite, Neponset Valley.
III.a. Rhyolitic facies of granite, Neponset Valley.

A comparison of the chemical composition of these three granitic facies is instructive in its bearing on questions of magmatic differentiation.

They all belong to class 1, order 4, i. e., they are persalic and feldspar is dominant over quartz; the batholith and the extreme peripheral facies are alike in rang (2), i. e., the alkalies are dominant in relation to the lime, and are separated only in the subrang; the batholith, with dominant soda, falls into subrang 4 and the rhyolite in subrang 3; the microgranite, distinguished by a lower percentage of lime, falls into rang 1, and like the rhyolite into subrang 3.

The variation in mineral composition of the three types accords with the chemical variation. The microgranite contains the highest percentage of quartz of the three facies, the lowest percentage of melanocratic constituents, the highest percentage of orthoclase and the most acid plagioclase. The rhyolite facies shows the next highest percentage of quartz and of orthoclase. It also shows the highest percentage of the basic constituents and the most basic plagioclase. The normal granite shows the lowest percentage of quartz and of orthoclase, a plagioclase of basicity intermediate between that of the microgranite and the rhyolite, and a percentage of the melanocratic constituents also intermediate between these types.

It is evident that the peripheral facies are more acid than the central body of the batholith and that this acidity does not increase continuously from center to periphery: the extreme peripheral border—the rhyolite—is more basic than the intermediate zone of fine grained granite. Magmatic differentiation by specific gravity and convection currents may have generated a more acid periphery and within this periphery differentiation by fractional crystallization has produced a more basic outer zone; crystallization, inaugurated here because of earlier cooling and following the general law of decreasing basicity, by means of diffusion would cause the residual zone of the periphery to become more acid than either the outer zone of the periphery or the granitic batholith.

The close resemblance in composition between the microgranite and the Quincy granite is suggestive: the microgranite is obviously the product of differentiation of a magma after intrusion (secondary differentiation); why may not the Quincy granite represent the product of differentiation of a similar magma prior to intrusion (primary differentiation)? Neither secondary nor primary differentiation have been carried far but since time is a factor in the process, the Quincy granite must under this view of its origin be younger than the Neponset granite.[7]

Intrusive and Effusive Igneous Rocks.

Granite Porphyry and Rhyolite Porphyry Dikes.—These dikes, traversing the granite are 75 to 100 feet in width; cut by rhyolite dikes, they are post-granitic and pre-rhyolitic in age. The best example of the type is a dike 100 feet wide exposed on Bearberry Hill, Stony Brook Reservation: the gray groundmass

[7] Since this study was made Dr. Laughlin on other evidence has reached a similar conclusion as to the relative ages of the Neponset and Quincy granites; see Contributions to the Geology of the Boston and Norfolk Basins, Massachusetts. 1. The Structural Relations between the Quincy Granite and the Adjacent Sedimentary Formations, Amer. Jour. Sc., vol. XXXII, 1911, pp. 17–32.

is here aphanitic and crowded with feldspar phenocrysts ¾ of an inch in diameter: large quartz phenocrysts are also conspicuous, especially on the weathered surface, which is light grey, buff, or green in color. The quartz phenocrysts show magmatic corrosion; the feldspar shows secondary alteration to sericite; repeated twinning and an extinction of 14° on 010 indicate an acid plagioclase of about the composition Ab_8An_1. Magnetite, chlorite, and epidote are distributed throughout the finely granular groundmass in large and small aggregates.

Northwest from Bearberry Hill the dike reappears with a granite-porphyry facies; the rock closely resembles the normal granite but possesses a conspicuously porphyritic texture; phenocrysts of quartz and acid feldspar crowd a microgranitic groundmass of the same constituents; the quartz shows corrosion and granophyric halos; the feldspar is for the most part plagioclase and albitic twinning prevails; albite of the composition Ab_5An_1 and more basic species are represented. The ferromagnesian constituent, an inconsiderable component of the rock, is precisely similar to that of the normal granite; in both rocks it is represented by a pleochroic green chlorite associated with magnetite; considerable secondary epidote is present associated with the feldspar and chlorite. The groundmass shows the granular and the granophyric fabrics.

In constituents and fabrics the type is more closely related to the granite batholith than to the rhyolitic flows. Farther to the northwest the rhyolite-porphyry facies recurs and is again replaced by the granite-porphyry; thus in a distance of a little more than a mile the dike twice varies from a rhyolite-porphyry to a granite-porphyry.

Aporhyolite Lava.—The normal granite and the peripheral facies are penetrated by acid and basic dikes and overlaid by what are now only scattered remnants of once extensive lava flows. The acid lavas, though considerably altered, bear plain textural evidence of their effusive origin; such evidence consists in the possession of fluxion, spherulitic, amygdaloidal, and perlitic fabrics. Another kind of evidence is found in the association of pyroclastics with the massive lavas; the coarser pyroclastics are readily recognized in the field by mottled weathered surfaces, produced by the inclusion of variously colored fragments in a light green or pink cement. The massive effusives exhibit a considerable range of colors and of textures; light green, gray, various shades of pink and purple and a brilliant brick red are the notable colors; an exceedingly dense, cryptocrystalline, felsitic texture, associated with conspicuous fluxion banding, is a widespread type of texture; a feature of the fine-textured lavas, which is also exhibited by modern lavas from the Lipari Islands, is an easy cleavage of the rock into lamellæ parallel to the fluxion planes, the rock which is very brittle, also breaks with a conchoidal fracture producing edges so sharp that they cut like glass.

In some localities, notably High Rock, Hyde Park, the lava is locally an aggregation of spherulites, varying in size from that of a pea to a butternut: the

spherulites either crowd the rock to the almost complete exclusion of a matrix or they are associated with, and imbedded in, a light green groundmass; their tints are pink or red or light-greenish yellow or all these colors arranged in concentric zones. None of these types are conspicuously porphyritic but they frequently exhibit small and inconspicuous phenocrysts.

Specimens of the massive rhyolite were obtained from exposures at the crossing by the New England Railroad of Blue Hill Avenue, and at Cook's Court, near Prospect Street, in Mattapan. At the latter locality fluxion banding and cleavage are notable. Specimens were also obtained from Blue Hill Avenue in Milton, where the occurrence is of a similar character and from Grew's wood, Hyde Park, where there is a ledge of porphyritic rhyolite. At the intersection of Arlington and River Streets, Hyde Park, occurs a red, eutaxitic rhyolite; the eutaxitic character, due to relatively silicious lenticular segregations, colored a deep red by hematite and influenced in form and arrangement by flow movement, is very conspicuous on the weathered surfaces; these lenses are often partially replaced by red jasper and present a superficial resemblance to amygdules, from which they may be distinguished by their lenticular form, which is unlike the spindle shape of the genuine amygdule. At High Rock, and in Grew's woods, Hyde Park, spherulitic lava is abundant; at Central Avenue and on Columbine Road, Milton, there is exposed a deep purple rhyolite, characterized by marked flow structure.

Petrographic character: The primary constituents which are still preserved in the acid volcanics are the alkali feldspars and quartz. There is some indication that members of either the pyroxene or amphibole group may have originally been present in very minor amounts, but no limemagnesian or ferromagnesian constituents remain.

Feldspar is the predominating constituent, forming some 60 per cent. of the rock and occurring in two generations; in the first generation the feldspar appears as small and scattered phenocrysts; as a component of the groundmass the feldspar may be granular, or lath-shaped, or acicular and radiating; the lath-shaped feldspars do not often show polysynthetic twinning and usually possess a parallel extinction; in the granular feldspar polysynthetic twinning is not uncommon and the microperthitic fabric is a conspicuous characteristic; extinctions indicate that *orthoclase*, *anorthoclase* and *albite* are the species represented, of which albite is the predominating species.

Quartz occurs rarely as a phenocryst, but is always a constituent of the groundmass. The secondary constituents are magnetite, pinite, epidote, kaolin, quartz, sericite, hematite, calcite and leucoxene.

To the iron oxides, which are disseminated as microscopic dust as well as in coarser aggregates, is owing largely both the record of early fabrics and the color of the rhyolites: all the red material owes that color to the presence of hematite; piedmontite occurs too rarely and too scantily to figure as a pigment; the purple rhyolites contain both magnetite and hematite as pigments; in the

case of the light-green lavas the color is owing, partly to the presence of epidote but chiefly to that of pinite,[8] a secondary product derived from the alteration of the feldspathic groundmass and the feldspar phenocrysts; the gray rhyolite owes its color to a freedom from iron oxide and to a comparatively fresh feldspathic character.

The fabrics found in these lavas are the granular, fluxion, trachytic, porphyritic, amygdaloidal, and spherulitic.

The granular fabric, consisting in a homogeneous quartz-feldspar mosaic, usually combined with flow-fabric, characterizes much of the lava; associated with this presumably secondary crystallization are microscopic colorless spherulites, usually occurring in bands; the radiating crystals of the spherulites are negative and feldspathic. When feldspar predominates in the groundmass the trachytic fabric is developed; the feldspar is lath-shaped and shows parallel extinctions or inclined extinctions with a small angle. These feldspathic volcanics recall the Westfalen quartz-keratophyres and the bostonite of Marblehead Neck.

Where the lava was originally vesicular, which is only rarely and never conspicuously the case, the vesicles are now filled with cryptocrystalline silica; crystals attached to the concentric walls of the lithophysal vesicles are replaced by silica.

The perlitic fabric is associated with the spherulitic, which is found most abundantly in the district west of West Street and in the mass constituting High rock, in Hyde Park. The slides of this material are crowded with spherulites spherical in form or polyhedral because of mutual interference; where the radiating fabric is well preserved, the fibers are both positive and negative; small phenocrysts of perthitic orthoclase often occur in the center of the spherulites. In many cases the original branching and spherulitic fabric is indicated in ordinary light only by the iron dioxide (hematite), while in polarized light an extremely fine granular quartz crystallization replaces the original fabric. In the groundmass associated with these altered spherulites are found flow fabric, perlitic parting, and a secondary micro-poikilitic fabric. The micro-poikilitic fabric may be combined with the spherulitic, or may replace it altogether, or may be confined to the groundmass.

Chemical Composition.

The following analysis of the acid volcanics of the Neponset Valley basin was made from composite samples carefully collected for the purpose. For comparative examination there are tabulated with it analyses of rhyolite and of keratophyre[9] from Marblehead Neck, of a soda granite[10] from the neighborhood of Cristiania and of a soda rhyolite[11] from Berkeley, California.

[8] W. O. Crosby, Relations of the Pinite of the Boston Basin to the Felsite and Conglomerate, Tech. Quart., February, 1889, pp. 248–252.

[9] H. S. Washington, op. cit., pp. 292–293.

[10] W. C. Brogger, Die Eruptivegesteine des Kristiania-gebietes, vol. I, p. 127.

[11] Charles Palache, Soda Rhyolite North of Berkeley, Bull. Dept. of Geol., vol. 0, p. 67.

	I.	II.	III.	IV.	V.
SiO_2	75.46	72.85	71.65	71.40	70.64
Al_2O_3	13.18	12.92	13.04	14.76	15.34
Fe_2O_3	0.91	2.98 (and MnO)	2.79	1.68	1.83
FeO			1.80	0.72	1.10
MgO	0.10	0.38	trace	0.55	0.52
CaO	0.95	0.90	trace	0.10	1.24
Na_2O	6.88	7.08	6.30	4.79	5.23
K_2O	1.09	3.01	3.98	5.16	3.55
H_2O+	0.93	0.65	1.10	...	0.14
H_2O-				1.46	0.38
TiO_2			trace	0.03	0.90
ZrO_2[12]					
	99.50	100.77	100.66	100.62	100.87

I. Spherulitic soda-rhyolite, Berkeley. Analyst, C. Palache.
II. Apo-soda-rhyolite, Neponset Valley. Analyst, W. H. Walker, Mass. Inst. of Tech.
III. Soda-granite, Kristianiagebiet. Analyst, L. Schmlek.
IV. Keratophyre, Boden's Point, Marblehead Neck. Analyst, H. S. Washington.
V. Rhyolite, northeast coast of Marblehead Neck. Analyst, H. S. Washington.

It is apparent that the acid flows of the Neponset Valley are related to rhyolites but differ from the normal type in their high content of soda. The predominant feldspar as shown by the slides is a soda-feldspar; as has been stated the slides give no clue to the character of the principal melanocratic constituents; the analysis shows that they must have been non-aluminous members of the pyroxene or amphibole groups. According to the older terminology the lavas are quartz-keratophyres or soda-rhyolites.

The chemical relationship to the old types of keratophyre is borne out by a general resemblance in the thin sections. The trachytic alkali feldspars of the groundmass, the perthitic orthoclase and the plagioclase phenocrysts, the absence of apatite and the paucity of the melanocratic constituents ally them with the quartz-keratophyres.

In accordance with a usage defined elsewhere[13] the acid volcanics of Neponset Valley are aporhyolites.

Norm.		Mode.	
Quartz	21.00	Quartz	20.7
Orthoclase	17.79	Orthoclase	17.8
Albite	49.78	Albite	50.0
Acmite	8.78	Ægerine	8.8
Wollastonite	1.86	Diopside	2.7
Enstatite	1.00		100.0
	99.01		

The rock is a phyri-kallerudose (class 1, order 4, rang 1, subrang 4). This name means that the phenocrysts are not notable megascopically, that the magma is persalic, quardofelic, peralkalic, and dosodic.

[12] The material was tested for P_2O_5 as well as MnO but no trace of these oxides were found.
[13] Bascom, op. cit., pp. 121–122.

NORMS.

	I.a.[14]		II.a.	III.a.[15]		IV.a.[16]		V.a.[17]
Quartz.....	28.9		21.00	20.3		22.8		23.3
Orthoclase	6.7		17.79	23.4		30.6		21.1
Albite.....	58.2		49.78	45.1		40.3		44.0
Anorthite.....	1.7	Acmite.....	8.78	7.4	Anorthite.....	0.6		6.1
Diopside.....	2.6	Wollastonite....	1.86		Corundum	1.1		0.6
Hypersthene....	0.5	Enstatite.....	1.00	3.0		1.4		1.3
Magnetite.....				0.5		2.4		0.7
							Ilmenite.....	1.7
							Hematite....	1.3

I.a. Noyangose (Class 1, order 4, rang 1, subrang 5).
II.a. Phyri-kallerudose (Class 1, order 4, rang 1, subrang 4).
III.a. Grano-kallerudose (Class 1, order 4, rang 1, subrang 4).
IV.a. Liparose (Class 1, order 4, rang 1, subrang 3).
V.a. Lassenose (Class 1, order 4, rang 2, subrang 4).

The rhyolites, aporhyolite, keratophyre, and soda-granite are alike in class and order, and with the exception of the Marblehead Neck rhyolite, which has a relatively larger percentage of lime, are alike in rang but differ slightly in the relation of the molecular weights of the alkalies. The keratophyre is sodi-potassic, the aporhyolite, soda-granite, and the Marblehead Neck rhyolite are dosodic and the California rhyolite persodic.

Aporhyolite Pyroclastics.—Fragmental volcanics are exposed near the crossing of Blue Hill Avenue by the New England Railroad; they are well displayed in ledges north of the railroad, on Blue Hill Avenue south of Brook Street, Milton; near Harvard Street and Mount Hope Cemetery; in a quarry near Mount Calvary cemetery, on Rutledge Road, Rugby, at the intersection of River Street and the New England Railroad, and south of Norfolk Street and the New England Railroad. Rhyolitic tuff and breccias are also well displayed in the district included between Grove and Washington Streets, West Roxbury, on Bold Knob, Stony Brook Reservation, and in Grew's wood. This tufaceous material varies from a fine-grained consolidated ash to a breccia composed of fragments one to two inches in diameter. In two cases the "aschen structur" which has been described by Mügge[18] is a feature of the tufaceous volcanic.

The forms which make up that texture appear only in ordinary light, and are obscured or completely lost with crossed nicols on account of an extremely fine quartz-feldspar mosaic which replaces the original fragmental and glassy texture of the lava. Where the recrystallization of fragments and matrix is not uniform, as is the case with the tufaceous material from Mount Calvary cemetery, the true character of the rock is obscured but not obliterated in polarized light. A large boulder of a blood-red color, found in the woods near Blue Hill Avenue, Milton,

[14] H. S. Washington, Professional Paper No. 14, U. S. Geol. Survey, 1903, p. 157.
[15] Op. cit., p. 155.
[16] Op. cit., p. 145.
[17] Op. cit., p. 173.
[18] O. Mügge, "Untersuchungen über die Lenniporphyre in Westfalen und der angrenzenden Gebieten," Neues Jahrbuch. f. Min. Geol. u. Pal., B. B. viii. 1893.

exhibits a fragmental texture, which is defined in ordinary light by red pigment and obliterated in polarized light by homogeneous crystallization; the original fragmental character is, however, indubitable. South of Norfolk Street and the New England Railroad a light green volcanic, breaking readily into slabs, shows the fragmental texture in spite of a uniform alteration of the replacing granular mosaic to pinite, which gives the light pea-green color to the rock. In other instances where the fragmental character of the rock is obscure in the hand specimen its obliteration is aided by the alteration of the secondary quartz-feldspar crystallization to pinite.

Where this mineral is not developed the tufaceous and brecciated character is always apparent in the hand specimen; the angular fragments exhibit a variety of shades,—pink, red, purple, green and other tints,—and often a fluxion arrangement; the material of the fragments is either quartz, feldspar (orthoclase, albite), aporhyolite or spherulites. The fragments of aporhyolite in many instances exhibit remarkably well preserved perlitic parting or fluxion fabric or "aschen structur"; in the tuff on Blue Hill Avenue south of Brook Street the fragments are mainly of aporhyolite, which has been recrystallized and largely altered to pinite and epidote, with orthoclase only of the original constituents remaining. Some fragments have a secondary spherulitic crystallization, in which case the spherulitic fibers are negative. Where the fragments are very heterogeneous in size and character, the rock may be termed an agglomerate; these agglomerates are of a green color, owing to the production of pinite, and contain in some cases fragments crowded with white kaolinized spherulites varying in size from a pin-head to a pea.

Between Mother Brook and the Providence Railroad there is exposed a tufaceous volcanic; from the same locality comes a specimen of crushed and recemented granite, composed of broken granitic quartz and feldspar cemented by a fine-grained siliceous crystallization; pinite is abundantly developed in this cement and gives its color to the rock, which includes no volcanic fragments. The aporhyolitic tuff is a purple and gray rock, free from pinite, with evidence of its clastic character disclosed on the weathered surface.

The localities where pinite is the predominating alteration product are the following: Near the crossing of Blue Hill Avenue and the New England Railroad; on Blue Hill Avenue south of Brook Street, Milton, and on Central Avenue, Milton; at the quarry near Mount Calvary Cemetery; at the intersection of Glenwood Avenue and River Street, Hyde Park; Stony Brook Reservation, Hyde Park; between Mother Brook and Providence Railroad, and, finally, south of the New England Railroad, on Norfolk Street, in Mattapan, where it is very characteristically developed. The development of pinite is much more marked in the tufaceous than in the massive volcanics, though not absolutely confined to the tufaceous material.

Rhyolitic Tuff.—Interbedded with lava flows and agglomerates in the West Roxbury volcanic neck is an exceedingly fine grained slaty rock obscurely showing

stratification. This material was first taken to be included Cambrian slate but proves on microscopic examination to be consolidated volcanic ash; comparatively fresh angular microscopic fragments of quartz and feldspar occur associated with a micro-crystalline matrix; considerable sericite has been developed.

The alkalies were determined as follows: Na_2O, 3.85 per cent., K_2O, 5.40 per cent. The total alkali percentage is about that of the lava, but the proportions are very nearly reversed. This is explained by the fact that soda silicate is acted upon more readily by solvents and replacing agents than is potassa; the development of sericite is evidence that the potassa practically remains in the rock; this tuff, like all the fragmentals, yields more readily to alteration than do the massive lavas; hence the abstraction of soda is not anomalous.

Aporhyolite Dikes.—The rhyolitic dikes which cut irregularly the normal granite and its peripheral facies are cryptocrystalline, dense, commonly but inconspicuously porphyritic, and banded by flow movement; they are either irregularly jointed or more commonly cleave parallel to fluidal lines; the less epidotized material is brittle and breaks with sharp edges; rarely a spherulitic fabric can be detected in the hand specimen.

The large dikes are usually dark red or purple in the central portion of the dike and greenish gray along the borders; the small dikes are usually gray throughout. Professor Crosby suggests that the rock was originally gray, that it was subsequently reddened by oxidation and later bleached by deoxidation along the borders through organic acids carried in the filtrating meteoric waters. A study of the sections shows iron oxide in the form of hematite distributed through the dark red material and granular epidote and sericite distributed through the greenish gray material. A comparison of the analyses of material from the center and from the edge of the dike shows a higher percentage of hygroscopic water in the material from the edge; the addition of water is essential to the production of epidote and sericite while the deoxidized ferric oxide (hematite) may have been utilized in the production of epidote. The red material, as has been stated, is free from hydration products.

The original constituents are quartz, feldspar, iron oxide, and a scanty ferromagnesian constituent, the original nature of which is somewhat in doubt, but which was probably biotite. The secondary constituents are sericite, epidote, chlorite, and hematite.

Feldspar occurs in two species and in two generations; the phenocrysts are an alkali feldspar, possessing about the composition Ab_8An_1 and an orthoclase; in the groundmass both orthoclase and an albite of a more acid composition occur (sometimes Ab). *Quartz* occurs only in the groundmass. The fabric of the groundmass is either micropoikilitic or orthophyric or spherulitic; with the first named fabric the feldspar is always narrowly lath-shaped, and the quartz occurs in irregular areas including the other constituents; with the orthophyric fabric the quartz fills the interstices; in the case of the last named fabric the spherulites do not possess regular and definite boundaries but a radial arrange-

ment of feldspar laths is the predominating fabric of the groundmass. Hematite is distributed as microscopic dust and in the form of trichites throughout the groundmass. Aggregates of epidote and chlorite occur as decomposition and hydration products of the feldspar and of the scanty biotite which, it is thought, was the original melanocratic constituent; a little sericite is developed in the orthoclastic feldspar.

The gray rhyolitic dikes show the same original constituents and a spherulitic fabric but have undergone, as might be expected, greater alteration. The spherulites which are of sufficient size to be seen with the naked eye, are arranged linearly and are replaced by spherical aggregates of sericite scales or less commonly by quartz; they are imbedded in a fine-grained granular aggregate of quartz and feldspar. Granular epidote is abundant throughout the groundmass and its formation seems to have absorbed the iron oxide which does not occur as free hematite in the gray rhyolite.

Chemical Composition.

Samples of the dark red center of the rhyolitic dikes from three of the specimens from which slides have been made and which represent as many different localities were taken for analysis. In the same way samples for analysis from three localities were taken of the greenish gray border of the rhyolitic dike.

	I.	II.	III.
SiO_2	73.72	71.73	72.85
Al_2O_3	13.22	15.00	12.92
Fe_2O_3	1.48	1.54	2.98
FeO	1.72	1.05	
MgO	0.66	0.86	0.38
CaO	0.65	0.69	0.90
Na_2O	4.52	4.69	7.08
K_2O	2.90	2.90	3.01
H_2O+	0.36	0.94	0.65
H_2O-	0.10	0.14	
CO_2	0.15	0.19	
TiO_2	0.34	0.35	no trace
P_2O_5	...	...	
MnO	less than 0.10	less than 0.10	
	99.82	100.08	100.77

I. Rhyolitic dike (center), Neponset Valley. Wm. T. Hall, analyst.
II. Rhyolitic dike (border), Neponset Valley. Wm. T. Hall, analyst.
III. Rhyolitic lava, Neponset Valley. W. H. Walker, analyst.

There is a great similarity in chemical composition as is to be expected between the two portions of the dikes. The alkalies and lime are practically the same. The chief difference lies in the increase in the border material of hygroscopic water, of magnesia and of alumina, and the decrease in silica and the ferric oxides. The increased proportion of magnesia and of alumina and the decrease of silica are very likely an original difference owing to the earlier cooling and crystallization of the border, which left a slightly more acid residual center. The

increase in hygroscopic water and the decrease in the iron oxides may be a difference owing to weathering; water has been added through the development of the epidote which, it has been stated, characterizes the border material; the iron oxides, which must have originally occurred in slightly increased instead of decreased percentage, have been abstracted when unappropriated by the epidote.

MODES.

	I.b.	II.b.		III.b.
Quartz	32.0	27.3		20.7
Orthoclase	17.3	17.4		17.8
Albite molecule	38.6	40.2		50.0
Anorthite molecule	3.4	3.4	Ægerine	8.8
Biotite	6.5	9.5	Diopside	2.7
Magnetite	2.2	2.2		
	100.0	100.0		100.0

NORMS.

	I.a.	II.a.		III.a.
Quartz	33.18	30.42		21.00
Orthoclase	17.24	17.24		17.79
Albite	38.25	39.82		49.78
Anorthite	3.34	3.34	Acmite	8.78
Corundum	1.43	2.86	Wollastonite	1.86
Hypersthene	3.15	2.33	Enstatite	1.00
Magnetite	2.09	2.32		
Ilmenite	0.61	0.61		
Water	0.46	0.08		0.65
CO_2	0.15	0.19		
	99.90	100.21		100.16

I.a. Phyri-kalluderose (Class 1, order 4, rang 1, subrang 4).
II.a. Phyri-kalluderose (Class 1, order 4, rang 1, subrang 4).
III.a. Phyri-kalluderose (Class 1, order 4, rang 1, subrang 4).

The resemblance between the rhyolitic dikes and flows is too close to admit of any doubt of a common magmatic origin.

Trachyte Lava.—In the woods on the west side of Central Avenue, Milton, there is exposed a deep purple volcanic with a conspicuously porphyritic structure. The rock is very feldspathic; the phenocrysts are white, broadly lath-shaped feldspars, numerous and with a considerable range in size; the groundmass is composed of a mosaic of feldspar grains, with little quartz. Twinning by the albite and Carlsbad laws are the rule; pericline twinning is rare; extinctions on 010 and 001 and the maximum equal extinction angles indicate that albite ranging from Ab to Ab_8An_1 is the predominating feldspar, although that orthoclase is also present is indicated by parallel extinction on some of the microliths. Lath-shaped and rudely hexagonal aggregates of magnetite and secondary quartz represent some ferromagnesian constituent whose substance has completely disappeared.

On the east side of the avenue a ledge of breccia furnished a pebble of a similar

rock; it shows some alteration to chlorite and epidote and calcite but on the whole is much fresher than the andesite, and is, like the porphyry just described, very feldspathic. The texture is panidiomorphic and the fabric porphyritic; the feldspars which constitute almost the entire rock are broadly quadratic, and in many instances show a central alteration to epidote or chlorite; repeated twinning is not common and parallel extinction shows that considerable orthoclase is present, though it is not the ruling feldspar; maximum equal extinction varies from 12° to 16°; extinction on untwinned sections is repeatedly 19° or 20°, from which it is inferred that albite is again the predominating feldspar. Aggregates of magnetite, chlorite, quartz, epidote and calcite as before represent the ferromagnesian constituent and suggest *biotite* by their forms.

In a cut on the New England Railroad near River Street station there is exposed a curiously brecciated porphyry. Aside from its brecciated appearance the rock resembles the purple porphyritic volcanic from Central Avenue, Milton, distinguished in the hand specimen by a lighter color; there is the same fine-grained granular groundmass crowded with lath-shaped and quadratic feldspars, not often showing polysynthetic twinning, but with albitic extinction angles.

Former ferromagnesian constituents are represented by areas of chlorite, epidote, quartz, and calcite, with heavy rims of granular magnetite.

Chemical Composition.

Fresh material for analysis was secured from a tunnel in Hyde Park which exposed more of this volcanic than it had before been possible to secure. An analysis of a similar rock (keratophyr) from the petrographical province of Essex County is tabulated with the Neponset Valley volcanic.

	I.	II.	III.
SiO_2	65.41	63.71	70.23
Al_2O_3	16.09	16.59	15.00
Fe_2O_3	3.84	2.92	1.99
FeO	0.95	0.66	....
MgO	1.51	0.90	0.38
CaO	2.93	3.11	0.33
Na_2O	6.54	8.26	4.98
K_2O	0.57	2.79	4.99
H_2O +	1.06		0.91
H_2O −	0.13	0.19	1.28
CO_2	0.47		...
TiO_2	0.51	0.86	0.03
P_2O_5	...		0.06
MnO	less than 0.10	0.20	0.24
S	trace	....	...
Total	100.01	100.55	100.42

I. Apo-soda-trachite, Hyde Park Tunnel. Wm. T. Hall, analyst.

II. Umptekite, Tuoljlucht, Umptek, Kola, Finland. W. Peterson, analyst, W. Ramsey, Fennia, XI, No. 2, p. 205, 1894.

III. Keratophyre, Boden's Point, Marblehead Neck. T. Chatard, analyst, Sears Bull. Mus. Comp. Zoöl., vol. XVI, p. 170, 1890; also Bull. 148, U. S. G. S., p. 78, 1897; also Jour. Geol., vol. VII, p. 293, 1899.

Norm.		Mode.	
Quartz	17.22	Quartz	13.8
Orthoclase	3.34	Orthoclase	3.4
Albite	55.02	Albite	55.7
Anorthite	13.07	Anorthite	7.3
Wollastonite	0.58	Biotite	12.0
Enstatite	3.80	Diopside	5.7
Magnetite	1.62	Magnetite	2.1
Ilmenite	0.91		100.0
Hematite	2.72		
Water	1.19		
CO_2	0.47		
	99.27		

Phyro-mariposose (Class 1, order 4, rang 2, subrang 5).

Norms.

	I.a.		II.a.[19]		III.a.[20]
Quartz	17.22				19.6
Orthoclase	3.34		16.7		29.5
Albite	55.02		69.2		41.9
Anorthite	13.07	Nepheline	0.3		1.7
Wollastonite	0.58	Acmite	6.9	Corundum	0.8
Enstatite	3.80	Diopside	5.0	Hypersthene	4.1
Magnetite	1.62	Wollastonite	3.9		
Ilmenite	0.91		1.7		
Hematite	2.72		2.6		
Water	1.19				
CO_2	.47				
	99.27				

I.a. Phyro-mariposose (Class 1, order 4, rang 2, subrang 5).
II.a. Umptekose (Class 2, order 5, rang 1, subrang 4).
III.a. Liparose (Class 1, order 4, rang 1, subrang 3).
[19] H. S. Washington, Professional Paper No. 14, U. S. Geol. Survey, 1903, p. 253.
[20] H. S. Washington, op. cit., p. 147.

The Neponset rock is a more pronounced soda-trachyte than is the Essex County type. Anorthoclase occurs in the latter but was not determined in the former.

Andesite Lava.—At the crossing of Blue Hill Avenue and the New England Railroad both acid and basic volcanics are exposed in the railroad cut; here the basic rock occurs as a dike in the acid eruptive. It is a compact, fine-grained, dark green chlorite rock, confusedly traversed by joint-planes; the weathered surface and the joint-planes are ironstained, and the latter are so numerous as to render it difficult to obtain a fresh fracture.

The specimens from this locality show a nearly complete alteration of mineral constituents with a preservation of texture. The alteration products are calcite, chlorite, quartz, epidote, and kaolin; epidote occurs as a cloudy yellow aggregate, filling the interstices of lath-shaped feldspars, the outlines of which still remain; the feldspar substance is so completely replaced by calcite, chlorite, kaolin scales, and quartz, as to render it impossible to determine the species. Magnetite is sparingly distributed and there are some remnants of iron pyrites undergoing alteration to limonite. The fabric is trachytic and inconspicuously porphyritic;

flow movement is indicated by the arrangement of the lath-shaped feldspar microliths.

West of Oakland Street and south of the New England Railroad, not far from the preceding locality, the basic volcanic occurs as an aphanitic dark purplish effusive, much jointed, with a development of chlorite on the joint faces, and frequently amygdaloidal.

This rock is characterized by comparative freedom from the alteration products—chlorite, calcite, and kaolin. The feldspar is accordingly fresher, and extinction measurements show that both orthoclase and an acid plagioclase are present. These feldspars with scanty calcite and much epidote and magnetite constitute the rock; the fabric is micro-ophitic combined with flow movement.

At the same locality there occurs a dike of the basic igneous rock which is lighter colored than the volcanic and shows much greater alteration of feldspar and matrix; the alteration, which has been carried too far for the determination of species, consists for the most part in the production of cloudy and granular epidote and of chlorite; magnetite is present; the fabric is trachytic where not obscured by secondary products.

On Norfolk Street, near Cook's Court, occurs a great mass of lava, which resembles the basic lava already described. It is very fine-grained and without peculiar fabrics; the original constituents are more or less completely replaced by calcite, chlorite, epidote, and quartz; the groundmass polarizes but faintly, and may have originally been in part glass; the feldspathic microliths are obscured in outline and in specific character.

On Morton Street, near Codman, in Dorchester, the basic volcanic occurs as an aphanitic dark green rock, obscurely mottled with areas of fine red jasper, which also coats the walls of cracks. The slides show the same fabricless or faintly ophitic groundmass, with epidote, chlorite, quartz, leucoxene, and the iron oxides as constituents, with altered plagioclase phenocrysts, and olivine phenocrysts completely replaced by hematite.

On Delhi Street, in Mattapan, occurs a volcanic, very like the Morton Street rock both megascopically and microscopially. As in the Morton Street volcanic the alteration to chlorite and epidote is so far advanced as to disguise the original constituents; one untwinned feldspar phenocryst whose substance has not completely disappeared shows an extinction on 010 of 14°; the groundmass polarizes very faintly and seems to be composed of altered orthoclase; there is considerable magnetite in the rock and some secondary quartz.

A basic volcanic exposed in a high ledge on the west side of Central Avenue, Milton, is coarse-grained and amygdaloidal, and greatly altered to epidote, chlorite, quartz, and calcite.

Where the feldspar is still comparatively fresh, the fabric is trachytic and porphyritic; again extinction angles show that the feldspar is orthoclase and an acid plagioclase of approximately the composition Ab_4An_1 or oligoclase. In this locality the rock exhibits a marked cleavage, parallel to which it breaks in parallelopipeds about one-quarter of an inch in thickness.

The Sewer Tunnel, Brook Road, Milton, furnishes lava with abundant and conspicuous amygdules of epidote and quartz.

Chemical Composition.

The following analysis of the rock was made from composite material carefully collected for the purpose from the localities represented by the slides. For comparative examination one of Brögger's basic akerites has been tabulated with the Neponset andesite.

The akerite possesses as mineral constituents plagioclase, a little orthoclase, diopside, biotite, magnetite, apatite, and a very little olivine.

SiO_2	53.75	55.00
Al_2O_3	18.37	20.81
Fe_2O_3	8.28	3.29
FeO		3.83
MgO	5.63	2.33
CaO	3.22	5.44
Na_2O	7.05	5.87
K_2O	1.20	0.16
H_2O+	3.34	0.55
H_2O-		
CO_2	trace	
TiO_2		
P_2O_5	trace	
MnO	trace	
Total	100.84	100.28

I. Apo-soda andesite, Neponset Valley. W. H. Walker, analyst.
II. Akerite, Ullernas, T. Forsberg, analyst. Brögger, Zeitsch. Kryst., vol. XVI, p. 49, 1890.

The mineral constituents may be recalculated as follows:

Norm.		Mode.	
Orthoclase	7.23	Orthoclase	7.4
Albite	37.73	Albite molecule	60.9
Nephalite	11.93	Anorthite molecule	15.5
Anorthite	14.73	Diopside	16.2
Diopside	1.11		100.0
Hypersthene	20.43		
Water	3.34		
	96.70		

Ophiti-neponsetose. Class 2, order 6, rang 2, subrang 5.

In spite of the predominance of albite in the slide, the remarkably high soda content was a surprise and the accuracy of the analysis was questioned. A new analysis was made but the result showed no alteration in the soda percentage.

The analysis falls within the chemical range of the andesites, though the ruling feldspar is more acid than is characteristic of the normal andesite. In accordance with the proposed use of the prefix apo these volcanics, which preserve the structures of the original type—a soda-andesite—while all constituents are more or less completely altered, may be termed *apo-andesite*.

No representative of class 2, order 6, rang 2, subrang 5, has thus far been

described, so far as the writer knows; the writer therefore proposes for this subrang the name *neponsetose;* this magmatic name means that the rock is dosalic, dolenic, domalkalic, and persodic.

Andesite Pyroclastics.—Associated with the massive andesite at Cooks Court and on Rockville Street near Blue Hill Avenue are andesitic tuffs: at Cooks Court, where the rock is composed of angular fragments of plagioclase, quartz, orthoclase, or basic and acid lava fragments, the tufaceous character is distinctly brought out by weathering; on Rockville Street, where a dark purplish-colored tuff is composed of heterogeneous fragments of andesitic lava, porphyritic or non-porphyritic or amygdaloidal, of aporhyolite and of jasper; these fragments are contained in an exceedingly fine-grained siliceous cement; the tuff though retaining original texture is completely altered mineralogically to chlorite, epidote, calcite, hematite, and magnetite.

Andesite Dikes.—Associated with the andesitic flows and cutting indifferently the granite, the micro-granite, the rhyolite, and the aporhyolite are basic dikes of a more recent age, ranging in width from an inch up to twenty odd feet. Material was obtained for study from exposures of such dikes at Coburn Street entrance of Stony Brook Reservation, on Bearberry Hill, at the end of Gordon Avenue, Hyde Park, and northwest of Winter Pond, Stony Brook Reservation.

Specimens from these localities show a dense, fine-grained to aphanitic, purplish gray or greenish purple rock with a scanty and inconspicuous feldspar phenocrysts. The weathered surface is a greenish brown and the rock is sometimes faintly mottled with green owing to chloritization.

The rock, originally very feldspathic is now almost completely metasomatized, with the fabric still preserved. The secondary minerals are epidote, calcite, chlorite, kaolin, and the iron oxides; epidote occurs in cloudy, granular aggregates and in transparent crystals; light green chlorite occurs in irregular allotriomorphic areas or in pseudomorphs after feldspar; the occurrence of calcite is similar; cracks traversing the rock are filled with calcite and quartz; aggregates of submicroscopic, brilliantly polarizing dust were considered to be kaolin; the iron oxides, magnetite and hematite, together with epidote grains, outline what were once lath-shaped feldspars and record the original orthophyric fabric.

The dike at the Coburn Street entrance to Stony Brook Reservation furnished the only material from which any clue to the character of the original constituents could be obtained. In this rock extinction determinations obtained on the feldspars, which constitute some 75 per cent. of the rock, showed that *orthoclase,* a little *anorthoclase* probably, and *labradorite* of the composition Ab_3An_4 were present. The original ferromagnesian mineral, which was a subordinate constituent, is in every case entirely replaced by secondary products, epidote and chlorite. Slender columnar crystals of apatite are still preserved as is often the case when other constituents are completely altered.

Chemical Composition.

The material for analysis was obtained from the localities mentioned above. The analysis of the andesitic effusive is tabulated with the analysis of the intrusive material for comparative examination.

	I.	II.
SiO_2	45.30	53.75
Al_2O_3	16.07	18.37
Fe_2O_3	8.26	8.28
FeO	2.17	
MgO	5.58	5.63
CaO	5.63	3.22
Na_2O	2.44	7.05
K_2O	4.06	1.20
H_2O+	2.93	3.34
H_2O-	0.30	
CO_2	4.78	trace
TiO_2	1.70	
P_2O_3	0.43	
MnO	0.20	
Total	99.85	100.84

I. Andesite dike, Neponset Valley. Wm. T. Hall, analyst.
II. Soda-andesite lava, Neponset Valley. Wm. H. Walker, analyst.

There is a general similarity between the two analyses. The only marked difference lies in the reduction in the intrusive rock of the soda percentage and a correlated reduction in alumina and silica. This corresponds with the difference in the feldspathic constituent observed in the petrographic study of the two volcanics.

The lava is characterized by a more acid plagioclase than is found in the intrusive rock; orthoclase is present in both. In neither volcanic can the melanocratic constituent be determined by microscopic investigation, in both types the alumina percentage is consumed by the feldspars; accordingly the melanocratic constituent was calculated as a non-aluminous lime magnesia silicate.

Norm.		Mode.	
Orthoclase	23.91	Orthoclase	26.1
Albite	20.96	Albite	23.
Anorthite	20.85	Anorthite	22.7
Wollastonite	1.97	Diopside	14.3
Magnetite	2.78	Magnetite	13.4
Apatite	1.01	Apatite	.5
Enstatite	4.10		100.0
Forsterite	6.86		
Hematite	6.40		
Ilmenite	3.19		
Water	3.23		
CO_2	4.78		
	100.04		

Orthophyri-shoshonose. Class 2, order 4, rang 3, subrang 3.

The chemical composition and mineral constituents are those of an andesite.

Acid Andesite Dikes.—There occur sparingly in this area dikes of medium acidity. On the border of the dike the rock is very fine-grained to aphanitic,

inconspicuously and minutely porphyritic; the central portion of the dike shows a less aphanitic texture and more conspicuous and numerous phenocrysts of pinkish or green epidotized feldspar, which extinctions indicate to be a feldspar between Ab_1An_1 and Ab_3An_4; no quartz is present; the ferromagnesian constituent is completely altered to actinolite or chlorite associated with epidote; apatite crystals are still well preserved; epidote occurs both as a granular aggregate and in good crystals; an orthophyric fabric is more or less traceable though extended chloritization and epidotization often obscure the original fabric as well as the constituents.

A complete analysis was not made of this type. The silica, alumina and iron oxides were determined as follows:

	Border of Dike.	Center of Dike.
SiO_2	60.00	62.8
Al_2O_3		19.84
FeO		8.70

The lime was found to be relatively low and the magnesia high.

These determinations suggest a hornblende bearing biotite-andesite. The material is too altered and the analysis too incomplete for more exact determination.

Diabase Dikes.—Cutting indifferently the members of the Neponset igneous complex occur two systems of diabase dikes; an east-west and a north-south system.

The east-west system includes very numerous dikes which vary in width from an inch to seventy-five feet; they are composed of a compact, fine-grained, dark-colored rock, of which the weathered surface is reddish brown, the interior gray-green, the fracture conchoidal, and the fabric micro-ophitic.

These dikes are cut by the north-south dikes, otherwise they cut all the other formations and represent the most recent igneous action in the district. They are characterized by a regularity of form, a parallelism of trend, and a continuity of occurrence not possessed by the other intrusives, nor do they show any relation in origin or composition to the other igneous materials of the basin.

Specimens were collected from dikes ten, twenty-five, forty, and forty-five feet in width; while the grain of the rock varies with the width of the dike, all of the material is finer grained than the Triassic diabase sheets and flows of Connecticut and New Jersey, and averages about the same in grain as the diabase of the Triassic dikes in eastern Pennsylvania.

Petrographically the rock is extremely uniform and presents no variations from the normal type of the Triassic diabase. In the hand specimen the ophitic structure is somewhat obscured by the uralitization of the feldspars, an alteration which is responsible for the green color of the rock. *Feldspar* occurs in the usual idiomorphic columnar crystals, but so altered that few extinction angles could be secured; these correspond to those of labradorite with the composition Ab_3An_4; a little orthoclase seems to be present in addition to the plagioclase feldspar.

Pyroxene is represented only by a violet gray augite occurring in considerable areas, always allotriomorphic and showing less alteration than the feldspar does. Iron oxide is present in the form of titaniferous magnetite and of ilmenite, both of which are abundantly altered to leucoxene, an alteration making more marked the cubic cleavage of the former mineral and the rhombohedral cleavage of the latter mineral which displays curiously branching forms. Apatite is abundant as is usual in this type of rock; olivine, biotite, and original hornblende are none of them present. The secondary constituents are uralite, actinolite, chlorite, epidote, albite, calcite, quartz, leucoxene, and pyrite; the first three are alteration products of the pyroxene; epidote in minute, stoutly columnar crystals, scanty albite, quartz, chlorite, and calcite are alteration products of the feldspar.

NEPONSET VALLEY IGNEOUS ROCKS.

	I.	II.	III.	IV.
	Batholith.			Acid Volcanics.
	Normal Granite.	Fine-grained Granite.	Rhyolitic Facies.	Aporhyolite Lava.
SiO_2	71.34	76.52	71.63	72.85
Al_2O_3	13.97	12.30	13.71	12.92
Fe_2O_3	1.95	0.70	2.09	2.98
FeO	1.00	0.56	1.76	
MgO	0.62	0.16	0.19	0.38
CaO	1.63	0.31	1.31	0.90
Na_2O	4.83	5.19	3.24	7.08
K_2O	3.89	4.58	4.49	3.01
H_2O +	0.80	0.41	0.51	0.65
H_2O −	0.09	0.11	0.08	
CO_2		none	0.41	
TiO_2	0.43	0.12	0.34	
MnO	trace	trace	trace	
P_2O_5			trace	
S			trace	
	100.55	100.96	99.76	100.77

V.	VI.	VII.	VIII.	IX.	X.
Acid Volcanics.		Intermediate.		Basic Volcanics.	
(Center) Dike.	(Border) Dike.	Trachyte.	Acid Andesite Dike.	Andesite Lava.	Andesite Dike.
73.72	71.73	65.41	62.80	53.75	45.30
13.22	15.00	16.09	19.84	18.37	16.07
1.48	1.54	3.84			8.26
1.72	1.05	0.95	8.70	8.28	2.17
0.66	0.86	1.51			5.58
0.65	0.69	2.93	Relatively low in	5.63	5.63
4.52	4.69	6.54	CaO and high in	3.22	2.44
2.90	2.90	0.57	MgO	7.05	4.06
0.36	0.94	1.06		1.20	2.93
0.10	0.14	0.13		3.34	0.30
0.15	0.19	0.47			4.78
0.34	0.35	0.51			1.70
trace	trace	trace			0.20
		trace			0.43
99.82	100.08	100.01		100.84	99.85

The system, trending north and south, includes dikes up to fifteen feet in width, the most recent igneous rocks of the province, basaltic in character, and characterized by a marked spheroidal weathering with the separation of successive rusty yellow oxidized coats. A specimen from one of the largest of these dikes exposed on Stimson Street shows considerable green hornblende and a finely diabasic structure.

NORMS.

BATHOLITH.

Granite.		Microgranite.		Rhyolite.	
	I.		II.		III.
Quartz	24.72	Quartz	30.48	Quartz	32.16
Orthoclase	22.80	Orthoclase	27.24	Orthoclase	26.69
Albite	40.87	Albite	37.73	Albite	27.25
Anorthite	5.00	Acmite	1.85	Anorthite	6.39
Wollastonite	1.28	Sodium metasilicate	0.98	Corundum	1.12
Enstatite	1.60	Diopside	1.43	Hypersthene	1.42
Magnetite	2.09	Hypersthene	0.60	Magnetite	3.02
Ilmenite	0.76	Ilmenite	0.15	Ilmenite	0.61
Hematite	0.48				
Water	0.89	Water	.52	Water	0.59
				CO_2	.41
	100.49		100.58		99.66

NORMS.

Neponset Valley Volcanics. Acid Volcanics.

	Effusive Aporhyolite IV.	Intrusives.			
			Center V.		Border VI.
Quartz	21.00	Quartz	33.18	Quartz	30.42
Orthoclase	17.79	Orthoclase	17.24	Orthoclase	17.24
Albite	49.78	Albite	38.25	Albite	39.82
Acmite	8.78	Anorthite	3.34	Anorthite	3.34
Wollastonite	1.86	Corundum	1.43	Corundum	2.86
Enstatite	1.00	Hypersthene	3.15	Hypersthene	2.33
		Magnetite	2.09	Magnetite	2.32
		Ilmenite	0.61	Ilmenite	0.61
Water	0.65	Water	0.46	Water	1.08
		CO_2	0.15	CO_2	0.19
	100.16		99.90		100.21

I. Grano-lassenose (Class 1, order 4, rang 2, subrang 4).
II. Grani-liparose (Class 1, order 4, rang 1, subrang 3).
III. Phyri-toscanose (Class 1, order 4, rang 2, subrang 3).
IV. Phyri-kallerudose (Class 1, order 4, rang 1, subrang 4).
V. Phyri-kallerudose (Class 1, order 4, rang 1, subrang 4).
VI. Phyri-kallerudose (Class 1, order 4, rang 1, subrang 4).
VII. Phyri-mariposose (Class 1, order 4, rang 2, subrang 5).
VIII. Ophiti-neponsetose (Class 2, order 6, rang 2, subrang 5).
IX. Orthphyri-shoshonose (Class 2, order 5, rang 3, subrang 3).

No analysis was made of the diabase of this district; presumably it offers nothing of peculiar interest.

Basic Volcanics.

Intermediate Trachyte.		Andesite.			
		Effusives.		Intrusives.	
	VII.		VIII.		IX.
Quartz	17.22				
Orthoclase	3.34	Orthoclase	7.23	Orthoclase	23.91
Albite	55.02	Albite	37.73	Albite	20.96
Anorthite	13.07	Anorthite	14.73	Anorthite	20.85
Wollastonite	0.58	Nephetite	11.93	Wollastonite	1.97
Enstatite	3.80	Diopside	1.11	Enstatite	4.10
				Fosterite	6.86
Magnetite	1.62	Hypersthene	20.43	Magnetite	2.78
Ilmenite	0.91			Ilmenite	3.19
Hematite	2.72			Hematite	6.40
				Apatite	1.01
Water	1.19	Water	3.34	Water	3.23
CO_2	0.47			CO_2	4.78
	99.27		96.70		100.04

General Discussion and Conclusions.

Chemical Characters.

The range in chemical composition is not very great; the rocks of this complex are, on the whole, acid and alkaline; disregarding the diabase, they range from a granite with a silica percentage of 76 to an andesite with a silica percentage of 45. The most acid type found in the district is the microgranite with 76.52 per cent. silica and the most basic type is the andesitic dike with 45.30 per cent. silica.

The alumina percentage does not vary greatly: it is lowest in the rhyolitic dike rock, 13.22 per cent., and highest in the trachyte where it is 16.09, which is but a slight variation from the percentage of alumina in the andesite, 16.07. The total percentage of the iron oxides is rather higher in the andesite and normal in the other types. Magnesia and lime are low in the acid rocks and nearly equal in value; they are much higher in the andesites and are again nearly equal in value.

The alkali percentages are high in all the types and soda is constantly present in greater amount than is potassa, except in the most basic type, the andesitic dike, where the two alkali oxides are present in about equal amounts.

In general the acid material is of normal acidity and the basic material of normal basicity; both are rich in the alkalies with predominating soda.

Mineralogical Characters.

In all this igneous complex, exclusive of the later diabase, the predominating feldspar is albite, as the universally high silica and soda percentages lead us to expect. While albite constitutes from 34 to 55 per cent. of the rocks, there is also always a considerable percentage of orthoclase present. The average amount in the granite is 25.5, in the rhyolitic volcanics 17.5, in the trachyte 3.4, in the

andesite, 7.4, with an increase in the andesitic dike to 26.1. In the rhyolitic lava the feldspar is purely alkaline and in all the types the lime molecule is very inconsiderable except in the andesitic dike, where it nearly equals the albite molecule producing a labradorite of the approximate composition Ab_1An_1.

Corresponding to the low magnesia percentage is a remarkable paucity in the ferromagnesian constituents; because of the alteration which these rocks have undergone, the nature of the melanocratic constituents can only be conjectured from the decomposition products and from the analyses; their amount does not exceed 11 per cent. in the acid material or 16 per cent. in the basic material.

Oxide Ratios.

$Na_2O : K_2O$. In all the rocks of the Neponset igneous complex the percentage of soda exceeds that of potassa: in the batholith the alkali ratio is highest in the granite (1.902) and lowest in the rhyolite (1.106); in the aporhyolite intrusives it is highest in the lava (3.563) and lowest in the center of the dikes (2.355); in the trachyte it is very high (17,500), higher than in any other type; in the andesite it is higher in the lava (8,692) than in the intrusive (1.00); in only one case is the ratio a whole number, nor does it often approximate a multiple and one half. In any one group of rocks there is greater range in the soda than in the potassa which remains comparatively stationary; if the trachyte and andesite be excepted, this is true of the whole series. In general Na_2O increases relative to K_2O with the decrease in SiO_2 as has been found to be the case in the Essex[21] and Christiania regions;[22] but this is not a uniform relation; the departure from this relation is greatest in the trachyte-andesite group where the relation is reversed; the highest alkali ratio is found in the most acid rock and the lowest in the most basic rock; this law of variation has also been found to hold true in other regions.[23]

$FeO : Fe_2O_3$. The variations in this ratio are slight and decrease is in direct proportion to the decrease in SiO_2. It ranges from 2 in the most acid rock, the fine-grained granite, to 0.576 in the most basic rock, the andesitic dike.

$Na_2O + K_2O : SiO_2$. This ratio, of course, increases somewhat with the decrease in SiO_2; it shows comparatively little variation ranging from .038 to .140; in the aporhyolitic series it is almost constant (.083, .09, .09).

$Al_2O_3 + Fe_2O_3 : CaO + Na_2O + K_2O$. This ratio, in general, increases with the decrease in silica and is never far from unity; the range is from .89 in the most acid rock—the fine-grained granite—to 1.247 in the andesitic lava; an exception to this statement is the ratio in the case of the border of the aporhyolite dike; the high ratio in this case (1.32) is due to an increase in Fe_2O_3, and to a less degree of Al_2O_3, in the border relative to the center.

$Al_2O_3 : CaO + Na_2O + K_2O$. This ratio is also very uniform and never far from unity; it cannot be said to vary with the acidity of the rock.

[21] H. S. Washington, Petrographical Province of Essex Co., p. 467, Jour. of Geol., vol. VII, 1899.

[22] Brögger, Eruptivegesteine des Kristianiagebietes, vol. III, p. 249, note 1, 1897.

[23] Pirsson, Bull. 139, U. S. Geol. Survey, p. 138, note 5, 1896. Harker, Geol. Mag., vol. IX. p. 203, 1892.

The magmatic classification of the igneous complex of Neponset Valley shows that magmatic differentiation had not proceeded far when the trachytic lavas were effused: with the exception of the andesite, the igneous rocks of the Neponset complex are alike in being persalic and quardofelic; the range of the alkali-lime ratio is a small one; the granite, rhyolitic periphery, and the trachyte are domalkalic; the other types, the microgranite, aporhyolite lavas and dikes are peralkalic; the range of the alkali ratio is also small and in every type the soda percentage is high; the microgranite and rhyolitic periphery are sodipotassic, the other types are dosodic with the exception of the trachyte which is persodic.

The andesites are the product of more prolonged differentiation and were therefore presumably effused later than the acid lavas; with a loss of free silica these volcanics are perfelic and lendofelic; the lava is domalkalic and persodic and the intrusive is alkalicalcic and sodipotassic. The intrusive is more basic than the effusive with a reduction of silica and of the soda-potassa ratio and an increase of the lime percentage; the youngest igneous rock of the province, exclusive of the diabase, is also the most basic.

The lavas of South Mountain, Pennsylvania, like the Neponset lavas represent the differentiation products of a soda-rich magma; unlike the Neponset volcanics the South Mountain volcanics represent the products of more extreme differentiation and lavas of intermediate composition are absent.

The South Mountain aporhyolite is an alaskose (class 1, order 3, rang 1, subrang 3), the meta-basalts are placerose (class 2, order 4, rang 3, subrang 5), and auvergnose (class 3, order 5, rang 4, subrang 3).

Description of a New Fossil Porpoise of the Genus Delphinodon from the Miocene Formation of Maryland

BY

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PLATES XVII–XXVI

PHILADELPHIA
1912

DESCRIPTION OF A NEW FOSSIL PORPOISE OF THE GENUS DELPHINODON FROM THE MIOCENE FORMATION OF MARYLAND.

By Frederick W. True, M.S., LL.D.

For more than twenty years, the present writer has interested himself in endeavors to accumulate in the National Museum a collection of specimens of North American fossil cetaceans sufficient to afford at least a fairly accurate idea of this portion of the extinct vertebrate fauna of America. The opportunities and resources for this undertaking have not been extensive and it is only recently that results of importance have been obtained.

In the earlier years the present writer visited the Nomini Cliffs and other points in Westmoreland County, Virginia, on the Potomac River, and collected vertebræ and fragments from other parts of the skeleton, nearly all of which were specimens which had been washed out from the cliffs and were picked up on the shore of the river. In 1905 he began work along the Calvert Cliffs in Calvert County, Maryland, on the west shore of Chesapeake Bay between Chesapeake Beach and the mouth of the Patuxent River. In 1908 and 1909 he was assisted by several members of the staff of the National Museum, including Mr. Wm. Palmer, Dr. M. W. Lyon, Jr., Mr. Norman Boss, and Mr. D. B. Mackie.

These later collections, in addition to vertebræ, teeth, humeri, etc., picked up on the shore of the bay, include one nearly complete skeleton (collected by Wm. Palmer), several skulls and portions of skulls (collected by F. W. True, Wm. Palmer, and D. B. Mackie), and various bones found in the cliffs and cut out by means of picks and knives. A considerable number of interesting specimens were contributed by persons who had visited the cliffs from curiosity, or in search of shells, sharks' teeth, etc.

The collection now assembled includes remains which seem calculated to throw important light on the fossil cetacean fauna of North America, and on the evolution of this order of mammals, as well as to clear up to some extent the obscurity surrounding the investigations of earlier writers, whose work was based on very insufficient material. The present paper is intended as the first of a series descriptive of the more important remains. As a preliminary, all the available types of North American species heretofore described have been examined. In this connection I wish to acknowledge, with very sincere thanks, the liberality of the authorities of various museums and other institutions in placing type-specimens in my hands for study, or allowing me access to them, including The Academy of Natural Sciences of Philadelphia, Johns Hopkins University, Goucher College, Harvard University, and the American Museum

of Natural History. I wish to express my obligations also for valuable assistance and information received from Mr. Witmer Stone, Dr. Wm. Bullock Clark, Mr. E. W. Berry, Prof. A. B. Bibbins, Dr. C. R. Eastman, Dr. W. D. Matthew, Dr. Paul M. Rea, and Mr. H. H. Brimley.

Numerous species of North American fossil cetaceans, as is well known, have been described from single teeth, a vertebra or two, or some other equally inadequate material, representing only a very small portion of the complete skeleton. In making known the more important remains now at hand, it has seemed to me best to describe them under new names when they cannot be positively identified with some form already characterized. It may be necessary at a later date to throw some of the names into synonymy, but this is perhaps a less evil than that important remains should bear a name which is of doubtful validity. It is, indeed, probable that the nomenclature of both American and European genera and species will need to be considerably modified when the Tertiary cetaceans are better known.

The fossil remains which, by permission of the Secretary of the Smithsonian Institution, will be described in this paper, comprise the larger part of a skeleton (Catalogue Number 7278, U. S. Nat. Mus.), obtained from the Calvert Cliffs, Calvert County, Maryland, on the west shore of Chesapeake Bay, one mile south of Chesapeake Beach. The skeleton was collected by Mr. Wm. Palmer, of the U. S. National Museum, on May 30, 1908. It was dug out of a stratum designated by the letter *B* on a sketch prepared by Mr. Palmer, at a point about 4 feet above high water mark.

This stratum is situated in one of the lower zones of lowest of the three Miocene formations of the Chesapeake Group in Maryland, which in the reports of the Maryland Geological Survey[1] is designated as the Calvert Formation. The Chesapeake Group was considered by Dr. Wm. H. Dall in 1898[2] as analogous to the European Helvetian. The Helvetian is included by Zittel[3] among the formations of the Middle Miocene. In 1904, however, Dall remarked that the Helvetian and Tortonian of DeLapparent represented "a fauna derived from the south, and of a subtropical character; hence, in no case strictly comparable with a fauna, like that of the American Chesapeake, derived from cool-temperate seas. It is to the fragmentary Miocene of North Germany and Denmark that we should look, if at all, to find the time-analogues of our Chesapeake species."[4] He further remarks: "In a general way, allowing for local peculiarities, the Miocene fauna of North Germany compares well and agrees closely with that of Maryland."[5] So far as I am aware, no cetaceans comparable with the form under consideration have been described from northern Germany.

The material consists of the following parts: (1) A nearly complete skull,

[1] Md. Geol. Surv. Report, Miocene, Text, 1904, p. xxix.
[2] 18th Ann. Rep. U. S. Geol. Surv., pt. 2, 1898, p. 334, table.
[3] Handb. Palaeont., pt. 1, IV, 1891–93, p. 65.
[4] Md. Geol. Surv. Report, Miocene, Text, 1894, p. cxliii.
[5] Op. cit., p. cliii.

with both halves of the mandible, 5 teeth in position in the upper jaw, and 8 in the lower jaw, and 30 additional detached teeth; one tympanic bone and one periotic; the larger portion of the hyoid; six cervical vertebræ and the centrum of a seventh; 9 thoracic vertebræ, 6 lumbar vertebræ, and 5 caudals;[1] about 25 detached epiphyses of vertebræ; 2 chevron bones; more than 17 ribs, some of them complete; one complete scapula and fragments of the other, both humeri and radii, and one ulna; a number of miscellaneous fragments.

Skull.

The skull (Pl. XVII, figs. 1–3; Pl. XVIII, fig. 1) in its present condition is 360 mm. long, and 171 mm. broad between the outer surfaces of the postorbital processes. It has been crushed downward so that the end of the zygomatic process nearly touches the top of the orbit. The end of the rostrum is nearly complete, but portions of the premaxillæ and of the left maxilla near the distal end of the rostrum are lacking. The right maxilla is much fractured near the distal end. Otherwise, the upper surface of the skull is nearly intact, except that the right orbital region is somewhat fractured and a little defective.

The inferior surface of the skull, though much fractured and distorted, especially proximally, is nearly complete, the principal parts lacking being portions of the palatal and pterygoid bones, and the proximal ends of the malars. One earbone is lacking. The posterior surface of the skull is much fractured and depressed, but nearly complete.

Superior Aspect (Pl. XVII, fig. 1).—The rostrum is a little longer than the brain-case, broad at the base and tapering gradually to the apex. The premaxillæ at the proximal end touch the nasals, being wedged in between them and the reflexed postero-internal border of the maxillæ. Opposite the nares, their internal border is concave and their external border convex. They are nearly plane in this region and very broad, the greatest breadth of each about equalling the portion of the frontal plate of the maxilla which lies external to it. The premaxillary and maxillary foramina are almost in the same line, and are slightly in advance of the maxillary notches. In the middle of the rostrum the premaxillæ are strongly convex and moderately high, while toward the distal end they are higher and more nearly plane and vertical.

The frontal plate of the maxillæ is nearly flat, but is doubtless somewhat distorted by pressure from above. The orbital and anteorbital borders of the plates are very thin, as in *Phocæna*. The anteorbital notches are broad and shallow. Immediately in front of them the surface of the maxillæ is horizontal but more anteriorly it slopes gradually downward as in recent delphinoids. At the middle of the rostrum the visible portion of each maxilla is about as broad as one of the premaxillæ. Behind the nares, the postero-internal borders of the maxillæ are separated by an interval of 30 mm., which is occupied by the frontals.

The posterior border of the nasals is not clearly defined but they appear to be

[1] An additional caudal which accompanied this material belongs to a larger individual and may not represent the same species.

oblong in form, each about 19 mm. wide and 22 mm. high, with a concave anterior surface and flat superior surface. They are nearly vertical in position, as in *Phocæna*, and rest on the upper border of the narial septum, which extends little, or not at all, above the level of the superior nares. The nares, taken together, are triangular in outline, with a maximum breadth posteriorly of 34 mm. The narial septum is low and does not extend backward as far as the premaxillæ, nor upward beyond the level of the nares. The mesethmoid extends but very little beyond the nares, and anterior to it the premaxillæ are widely separated, as in *Sotalia* and *Steno*, so that the deep vomerine trough is plainly visible.

The posterior exposed border of the frontals at the sides of the vertex is very narrow, having an antero-posterior breadth of about 5 mm. At the vertex, the space between the supraoccipital and nasals, occupied by the frontals, appears to be about 27 mm., antero-posteriorly. This anterior median extension of the frontals is not elevated above the adjoining bones.

Lateral Aspect (Pl. XVII, fig. 3).—The most noticeable features of the side of the skull are the large size of the orbit, and the thinness of the frontal and maxillary plates above the same. The anteorbital region is not elevated or thickened. The postorbital process is triangular, slender, and elongated. The temporal fossæ were apparently of large size, but the skull is too much distorted in this region to permit a determination of their form.

The zygomatic process, seen from without, is oblong, elongated, and truncated at the extremity, having about the same form as in *Sotalia*. The postglenoid process is moderately long and curved forward.

Inferior Aspect (Pl. XVII, fig. 2).—The surface of the palate is convex proximally. The vomer is visible somewhat posterior to the middle of the rostrum as a rather broad, elliptical area about 43 mm. long and 7 mm. broad.

On either side of the vomer, a foramen is visible in the maxillæ. From these foramina grooves extend forward in the median line, and together with the shelving internal border of the maxillæ cause the palate to be quite deeply concave in this place, as in the ziphioids. On account of imperfections, it is impossible to determine how much of the distal portion of the palate is formed by the premaxillæ. These bones appear to be broad and inclined inward near the extremity of the rostrum, but the line of demarcation which is visible may be a fracture rather than a sutural line.

The palatine bones are not clearly marked off from the adjacent portion of the maxillæ, but appear to differ from the form found in the majority of recent delphinoids, in that the anterior margins of the two bones do not diverge from the median line, leaving a V-shaped area between them, but are in contact nearly to the most anterior point, while laterally there is a deep emargination on either side. A depression occupies a large portion of each palatine bone near the median line posteriorly, with another, less deep, external to it. These bones, therefore, resemble those of *Eurhinodelphis*, as shown in the figures of Professor Abel,[1] rather more closely than those of any other genus.

[1] Mém. Mus. Roy. Hist. Nat. Belg., I, 1901, pl. 8; II, 1902, pl. 13.

At the posterior end, the palatines present a deep transverse channel, which represents the base of the pterygoid sinus. The pterygoid bones themselves are too defective to permit a determination of their original form. The region of the posterior nares is also much fractured and distorted.

The descending wings of the basioccipital, or that portion against which the tympanic bones rest, are peculiar in that they are traversed by a strong, inferior ridge, directed obliquely outward and backward. The area behind the ridge is concave. This conformation is unlike any which I have observed in other forms, and may be regarded as characteristic of the species. The free, inferior extremity of the exoccipital extends considerably below that of the wings of the basioccipital, while in recent delphinoids the two are about on a line, or else the basioccipital is the longer. The free extremity of the exoccipital above mentioned, seen from below, presents a semicircular outline, and a concave surface.

The condyloid foramen is situated posterior to the deep channel between the exoccipital and the descending wings of the basioccipital, as in *Eurhinodelphis*, instead of in the bottom of the channel itself, as normally in recent delphinoids.

The postglenoid process of the zygomatic is very prominent, and is cut off from the portion of the zygomatic which adjoins the exoccipital by a very distinct groove. The glenoid fossa is comparatively narrow and elongated.

The inferior surface of the orbital plate of the frontals is broad, smooth and only moderately concave. The anterior basal portion of the malar consists of an almond-shaped bone, broad and thin toward the median line, and narrower and thicker at the outer free extremity where it is inserted between the frontal and maxilla, and forms the outer portion of the maxillary notch. The posterior margin of this bone, which forms the antero-internal portion of the roof of the orbit, is convex backward. The styloid portion of the malar appears to be inserted at the extreme anterior angle of the expanded portion, but as the sutural lines are not distinct, the latter may extend somewhat beyond the former anteriorly. As already mentioned, the malar forms the whole of the outer wall and base of the maxillary notch, the maxilla stopping just short of the notch anteriorly. The styloid portion of the malar which remains is about 23 mm. long, very slender and tapering. The posterior portion may have been cartilaginous.

The basal portion of the malar above described may, of course, represent the lachrymal, as it does in recent delphinoids, but there is no clear separation as there is in the ziphioids. This is of importance because, as is well known, the lack of a distinct lachrymal bone is one of the characters of the family Delphinidæ.

A noticeable feature of this skull, when viewed from below, is the short distance between the last maxillary tooth and the base of the maxillary notch, which is but 22 mm.

Posterior Aspect (Pl. XVIII, fig. 1).—As already remarked, the skull has been much distorted by pressure from above, the supraoccipital having been fractured just above the condyles, and the top of the skull pressed down, so that the roof

of the orbit almost touches the extremity of the zygomatic process. In consequence, the original form of the supraoccipital cannot be accurately determined. The superior border was, however, evenly rounded, and did not overhang the vertex. The surface is concave in the median line, with no trace of a ridge. The posterior borders of the temporal fossæ were widely separated, as in recent delphinoids.

The occipital condyles are small, widely separated above, but approximated below, where the interval between them is only 15 mm. Their surface is somewhat pitted, indicating that the individual is immature.

Mandible (Pl. XVIII, figs. 2 and 3).—The mandible is large compared with the size of the cranium, and the rami less slender than in many recent species of *Delphinus*, *Sotalia*, etc. The superior border is quite evenly concave from the anterior extremity to the coronoid process. The inferior border is concave in the proximal two-thirds, and convex distally. The ramus is slenderest at the middle of the length of the jaw. The coronoid region is especially elevated, the distance between the coronoid process and angle amounting to more than one-fourth the total length of the jaw, while in recent species of *Delphinus*, *Sotalia*, and *Steno* it is much less than one-fourth, or even less than one-fifth. The symphysis is very long, being almost exactly one-third the length of the jaw. The conformation of the proximal end of the jaw internally is similar to that of recent delphinoids, except that the extremity of the coronoid process is concave, with a channel running forward immediately below the superior border of the jaw and reaching nearly to the tooth-row. The angle is lacking on both sides of the mandible, but appears to have extended nearly to the line of the condyle. The border of the jaw immediately in front of the angle is curved inward and very thin. The condyle is small and elliptical, with the long axis vertical. The margin of the jaw from the top of the condyle to the extremity of the coronoid process is nearly straight, the process itself not being recurved, as it is in many recent delphinoids.

The superior surface of the symphysis is narrow and nearly horizontal. On the outer side of the ramus, opposite the symphysis, are several large foramina, from each of which a canal extends some distance forward. There is, however, no distinct channel near the inferior margin of the jaw, as in *Cyrtodelphis*, *Platanista*, *Stenodelphis*, etc. One rather large elliptical foramen is situated about in line with the middle of the tooth-row.

MEASUREMENTS OF THE SKULL.

	Mm.
Total length of skull	360
Greatest breadth across zygomatic processes	163
Breadth across centers of orbits	155
Breadth of rostrum at maxillary notches	92
Breadth of premaxillæ at same point	57
Breadth of rostrum at middle	36
Breadth across premaxillæ at same point	18
Greatest breadth between outer borders of premaxillæ opposite nares	92

Greatest breadth of each premaxilla at same point	39
Greatest breadth between premaxillæ at base of rostrum	11
Distance between proximal ends of premaxillæ	39
Greatest breadth of frontal plate of each maxilla external to premaxilla	39
Distance between proximal ends of maxillæ	31
Distance between proximal ends of maxillæ and supraoccipital	7
Greatest thickness of maxilla over orbit	1
Greatest breadth of superior nares	32
Depth of rostrum at base	37
Depth of rostrum at middle	20
Length of orbit	51
Length of postorbital process	29
Length of temporal fossa	80?
Length of zygomatic process from exoccipital	50
Least breadth between temporal fossæ	131?
Height of supraoccipital above foramen magnum	65?
Breadth of foramen magnum	39
Height of each occipital condyle	36
Breadth of each occipital condyle	21
Length of portion of vomer visible on palate	51
Distance from last alveolus to maxillary notch	22
Length of largest superior alveolus	7
Least distance between alveoli	1
Total length of mandible	296
Length of symphysis	94
Height of mandible at coronoid process	72
Height of mandible at middle of length	23
Height of mandible at posterior end of symphysis	23
Height of each condyle	22
Breadth of each condyle	13
Distance from posterior end of symphysis to last alveolus	86
Length of largest mandibular alveolus	8
Least distance between alveoli of same side	1
Distance between alveoli of opposite sides at symphysis	7.5

Teeth.

(Plate XIX, figs. 1 and 2; Plate XXVI.)

The last three maxillary teeth on the right side, and the last two on the left side are in position (see Pl. XVII, fig. 2). Of the mandibular teeth (see Pl. XVIII, figs. 2, 3) the last four on the right side are in position, and three others near the middle of the jaw; on the left side, only the penultimate tooth. In addition, numerous detached teeth have been preserved. The dental formula was originally about $\frac{27-27}{26-26}$. The mandible is almost intact, so that the number of teeth in the lower row can be ascertained with considerable exactness, but the distal end of the rostrum is not sufficiently complete to allow of an accurate count of the upper row. The number above and below, however, is not likely to have differed by more than one or two teeth on each side.

The teeth are large, relatively, and very close together, and are of extraordinary form in that the crowns of the posterior ones are trituberculated, while all the crowns of teeth have more or less strongly developed anterior and posterior longitudinal ridges, and rugose enamel.

The total number of teeth originally present, as indicated above, was about 106, of which 43, or about two-fifths, are preserved. As those available are of different forms and sizes, and are apparently from both jaws, it is allowable to suppose that they represent quite fully the different forms characteristic of the series. These teeth have been arranged and numbered in accordance with certain indications which will be described below, beginning at the posterior end of the series in each jaw.

The series as a whole has the following characteristics: The largest teeth have a length of 29 mm., and a maximum diameter of 5 mm. The smallest teeth are 20 mm. long, and have a maximum diameter of 4 mm. The crown of each tooth occupies about one-third the length of the tooth (except as indicated below), and is acute and strongly curved inward, especially at the posterior end of the series. The posterior maxillary tooth on the left side has two distinct cusps, one in front of the other, and a less prominent cusp behind them. On the right side, the cusps are less prominent. Three or four teeth at the posterior end of the series, on either side, present an antero-internal and a postero-internal basal cusp, and below each a smaller one, which should perhaps be regarded as merely a prominence on the cingulum. Indications of these basal cusps are distinguishable on some of the more anterior teeth, but die away and disappear at the distal end of the series. The apex of the crown is most strongly incurved at the posterior end of the series and less so anteriorly. As already mentioned, each tooth has an anterior and a posterior longitudinal ridge on the crown. At the posterior end of the series, the anterior ridge is divided into two, which diverge toward the base of the crown. The amount of divergence is large in the teeth at the posterior end of the row, but diminishes gradually on each succeeding tooth anteriorly, and at the distal end of the row is reduced to zero, the anterior teeth presenting only a simple ridge anteriorly and a similar one posteriorly.

The cingulum is not very distinct on any of the maxillary teeth, except at a point just internal to the base of the posterior longitudinal ridges, where in some cases, especially near the middle of the series, it forms an appressed, raised area, with a crenulate upper margin. In other instances, it is represented only by a horizontal basal extension of the ridge.

The rugosities of the enamel of the crown are sufficiently coarse to be discernible with the naked eye. They consist of very numerous rounded ridges of varying size and length, and are for the most part longitudinal. In the anterior teeth, as already mentioned, the rugosities, though present, are much less distinct.

The roots are slender, elongated and curved backward at the extremity. They are somewhat gibbous near the junction with the crown. Both the upper part of the root and the crown are flattened anteriorly and posteriorly.

The mandibular teeth are similar to the maxillary teeth in form, but in the posterior tooth the accessory cusps are less distinct than in the penultimate tooth, and the two or three which precede it. In these there is a distinct postero-

internal accessory cusp, on a lower level than the main cusp, and also a smaller antero-internal accessory cusp situated a little lower. As in the maxillary teeth, there is below the postero-internal cusp a smaller protuberance which may, perhaps, be regarded as a part of the cingulum, and a similar one below the antero-internal cusp. The posterior cusp may be distinguished at least as far forward as the 7th tooth from the posterior end of the series, and the prominence of the cingulum still farther forward. On the posterior teeth of the series, the posterior longitudinal ridge traverses the postero-internal accessory cusp. The height of the crown increases a little toward the anterior end of the series, and among the teeth preserved is one which has a longer crown than the average of the others, and is less curved and nearly terete and smooth. This is probably one of the terminal mandibular teeth.

The cingulum is more strongly developed than in the maxillary teeth, appearing not only at the base of the longitudinal ridges, but also around the bases of the accessory cusps. In the middle of the series, it is distinguishable nearly, or quite, around the teeth.

The roots of the teeth which are regarded as belonging to the mandibular series are less curved than those of the maxillary ones, or nearly straight, but not otherwise different. In both series the roots are of a chocolate-brown color, while the crowns are of a much paler, yellowish brown. The teeth are hollow and the tapering extremity of the root open below.

The dimensions of the teeth are given in the following table. The numbers used to designate the teeth which are in the natural position show their actual place in the row, counting from the posterior end. The numbers for the detached teeth are arbitrary, but the latter are arranged as nearly as possible in what is believed to be the natural sequence, no allowance being made for missing teeth, or for those *in situ*. The total length is given for each tooth as now preserved, but as many have the root defective this measurement in the majority of cases will be of little use, except in identifying particular teeth in any discussion of

MEASUREMENTS OF THE TEETH.

Measurements.	Upper.											
	Left, *in situ*.		Left, detached.									
	1	2	1	2	3	4	5	6	7	8	9	10
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Total length	—	—	29.4	26.8	26.6	27.2[1]	27.2[1]	25.5[1]	21.0[1]	14.0[2]	19.8[1]	11.9[2]
Length of crown	7.6	8.2	9.8	9.6	9.9	10.8	11.4	10.6	10.4	10.2	8.9	10.8
Greatest diameter of crown at base	5.0	5.0	5.6	5.0	5.2	5.1	5.4	5.6	5.3	5.2	4.3	—
Greatest diameter of root	4.6	5.2	5.5	5.6	5.6	5.5	5.7	5.6	5.4	—	4.6	—
Least diameter of extremity of root	—	—	1.5	1.8	1.4	2.0[1]	2.0[1]	2.4[1]	—	—	2.1[1]	—

[1] Root a little defective.
[2] Root defective.
[3] Nearly all of root lacking.

MEASUREMENTS OF TEETH (*Cont.*).

Measurements.	Upper.										
	Right, *in situ*.			Right, detached.							
	1	2	3	1	2	3	4	5	6	7	8
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Total length	—	—	—	26.0[1]	26.4	24.9[1]	24.5[1]	17.9[3]	20.7[2]	13.1[3]	14.1[3]
Length of crown	6.8	7.6	8.7	10.0	11.4	10.7	11.0	10.9	9.3	10.6	8.8
Greatest diameter of crown at base	4.2	5.1	5.4	5.2	5.3	5.3	5.4	5.3	4.7	5.5	4.2
Greatest diameter of root	4.1	5.1	5.2	5.4	5.5	5.5	5.7	5.8	5.3	—	—
Least diameter of root at extremity	—	—	—	2.1[1]	1.8	2.1[1]	2.0[1]	—	—	—	—

MEASUREMENTS OF TEETH (*Cont.*).

Measurements.	Lower.							
	Left, *in situ*.		Left, detached.					
	1	2	1	2	3	4	5	6	7
		mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Total length		—	25.8[1]	26.9	19.9[2]	—	24.5[2]	22.4[2]	19.3[2]
Length of crown	Lacking.	8.0	8.4	8.5	8.8	9.3	10.0	11.8	11.0
Greatest diamer of crown at base		5.2	5.6	5.4	5.3	5.5	5.3	5.2	5.0
Greatest diameter of root		5.?	5.5	5.5	5.4	—	5.8	5.6	5.5
Least diameter of root of extremity		—	2.3[1]	1.8	—	—	—	—	—

MEASUREMENTS OF TEETH (*Cont.*).

Measurements.	Lower.											
	Right, *in situ*.							Right, detached.				
	1	2	3	4	8	9	10	1	2	3	4	5
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Total length	—	—	—	—	—	—	—	27.6[1]	22.9[2]	18.5[3]	21.7[2]	22.2[2]
Length of crown	7.0	8.2	8.4	8.9	9.0	9.6	9.6	9.5	10.9	10.9	9.9	11.7
Greatest diameter of crown at base	4.7	4.9	5.1	5.3	5.6	5.5	5.5	5.4	5.4	5.6	5.0	5.0
Greatest diameter of root	4.6	4.8	5.1	5.3	5.5	5.3	5.2	5.8	5.5	5.4	5.0	5.7
Least diameter of extremity	—	—	—	—	—	—	—	2.5[1]	—	—	—	—

them which may take place hereafter. Teethnot marked defective are complete, but only a few dimensions of those *in situ* can, of course, be given. The measurements of the diameter of the root in the latter are probably rather too small, as the largest diameter usually lies below the level of the margin of the jaw.

EARBONES.

The left periotic bone, and the larger part of the right tympanic bone have been preserved.

Tympanic (Pl. XXV, figs. 12, 13).—The portion of the tympanic preserved comprises the inner and lower surfaces. It is 34 mm. long and 16 mm. broad.

Originally it was probably about 20 mm. broad. Viewed from below it is oblong, nearly flat, and not sharply acuminate anteriorly; posteriorly it is divided along the median line by a deep, angular sulcus, which extends forward to the middle point of the length. The internal posterior lobe is angular, while the external one appears to have been globose, and probably did not extend much, if any, beyond the internal one.

Viewed from above, the involution of the inner lip is narrow and sinuous in outline. The interior of the bulla is not distinctly divided into two depressed areas separated by a transverse ridge, as in *Schizodelphis*, but presents two quite shallow depressions, separated by a wide, flat area covered with small tubercles. The orifice of the Eustachian canal is very broad, as in *Delphinus*, *Phocæna* and other recent delphinoids.

Periotic (Pl. XXV, figs. 6, 7).—The periotic is 30 mm. long and 18 mm. broad at the posterior end. It resembles the same bone in *Delphinus*, *Prodelphinus*, *Sotalia* and *Phocæna* in general form, having, perhaps, the closest similarity to that of *Delphinus*. Viewed from above, the bone is oblong, nearly flat, with truncated anterior end and transverse posterior end, the outline of the latter being rounded, and terminating, of course, in the tympanic process.

Viewed from within, the petrosal is seen to be only moderately large and to be situated near the middle of the length of the periotic, not strongly inclined forward and with a nearly straight inferior outline. The anterior and posterior process of the periotic from this point of view are of about equal length. Seen from within (or the tympanic aspect) the tympanic process appears as a rounded, slightly concave facet, smaller in diameter than the petrosal.

Hyoid Bone.

The hyoid bone (Pl. XXV, fig. 5) is nearly complete, the missing parts being the distal end of the right stylohyal, and the middle portion of the left stylohyal. The basihyal is separate from the ceratohyals, on account of immaturity.

The stylohyals were originally about 90 mm. long, and have a maximum breadth of 15 mm. The mastoid, or proximal, end is elliptical, with the long axis at right angles with the shaft of the bone. The shaft is depressed triangular, flat dorsally (or posteriorly), and convex ventrally, with the highest part near the external border. This border is slightly convex, while the internal border is concave. The distal end, or that which joins the basihyal, is oblique and rounded.

The basihyal is a thin, irregularly hexagonal bone, about 36 mm. in diameter, with a rather deep anterior emargination, a convex posterior border, and two pairs of articular facets, of which the posterior is the larger. The superior and inferior surfaces are both concave.

The ceratohyals are 57 mm. long, with a maximum diameter of 18 mm. The external border is convex and the internal border arcuate. The ventral (or anterior) surface is nearly flat, while the dorsal is convex. The proximal end is thick and elliptical in outline; the distal end, tapering, thin, and rounded.

VERTEBRÆ.

The vertebræ are especially noteworthy in that all the cervicals are separate. As already stated, the vertebræ preserved comprise 6 cervicals and the centrum of one other; 9 thoracics; 6 lumbars; and 5 caudals. All the epiphyses are free. Many of them have been preserved, however, and have been glued to the centra.

CERVICALS.

Atlas (Pl. XIX, figs. 3–13).—The atlas is separate from the axis and nearly complete. It has a maximum height of 64 mm. and a breadth of 76 mm. In general form it most resembles the same vertebra in *Delphinapterus*, *Sotalia* and *Delphinus*, among recent genera, but differs from all three in many of its characters. It is relatively short antero-posteriorly, the length being about one-fourth the breadth. The anterior articular facets are large, moderately deep, and not strongly divergent. They are separated below by a rather wide interval, measuring about 19 mm. The neural arch is low, and is broad antero-posteriorly and pierced on each side by a large elliptical foramen, the long axis of which measures 11 mm. The foramen is completely surrounded by bone. A single transverse process is present on each side of the centrum, about in line with the junction of the middle and lower thirds of the anterior articular facets. The process is short, stout, and strongly curved backward.

The posterior articular facets are moderately convex and oblong, with a nearly straight, vertical external border, which is distinctly marked off from the posterior surface of the centrum. This posterior surface, external to the facets, is very broad and nearly flat. Its free margin is very prominent and its outline arcuate when viewed from the side. The margin joins the transverse process below. Between the posterior articular facets is a concave, nearly horizontal facet for the odontoid process of the axis. Below it, the posterior median portion of the centrum is slightly prolonged obliquely downward and backward, and presents on its posterior surface, on each side of the median line, a pair of shallow pits resembling alveoli, and below them two short, acute projections. The neural spine is very low, somewhat longer than the arch antero-posteriorly, and has a nearly straight free border which is inclined downward anteriorly.

Axis (Pl. XIX, figs. 3, 4).—The axis has a maximum height of 70 mm. and a maximum breadth of 79 mm., while the greatest thickness, antero-posteriorly, is about one-fourth the breadth, or 19 mm. In general form it closely resembles the axis in *Delphinapterus*, though the transverse process is lower, and the neural spine smaller and lower. The whole vertebra is less thick.

The anterior articular facets are large, pyriform, or oblong, and only slightly concave. They are separated below by an interval of 28 mm. The neural arch is broad and thin; concave anteriorly and convex and oblique posteriorly. The neural spine is a thick process, oblong in outline when viewed anteriorly, and triangular when viewed laterally. The free margin is transverse and rounded. In the median line anteriorly is a sharp longitudinal ridge, and posteriorly a

corresponding furrow. The neural canal is large and oval. The posterior zygapophyses are salient, nearly horizontal, and situated nearly as high up as the top of the neural canal. The odontoid process is only slightly produced anteriorly, but bears on its inferior surface a large convex facet, which articulates with a similar concave facet on the centrum of the atlas, as in *Delphinapterus*.

The single transverse process is much larger and longer than that of the atlas. It is oblong, broad vertically, and rather thin antero-posteriorly, the free end blunt and rounded. The process is directed obliquely backward and outward. Viewed from behind, the centrum shows the larger, rather concave surface for articulation with the third cervical, and on each side a broad, imperforate, concave surface ending in the transverse process.

When the atlas is imposed on the axis, and the two vertebræ viewed from in front, the parts visible very closely resemble in form those of *Steno* and other delphinoid genera. When viewed from below, a notable difference is observable, in that the transverse process of the axis is much longer than that of atlas, the reverse being true in *Steno* and other recent delphinoids.

3d Cervical (Pl. XIX, figs. 7, 8).—The 3d to the 7th cervicals are all very thin, as in recent delphinoids, and present substantially the same characters as are found in such genera as *Steno*, *Tursiops*, etc. In the 3d, the centrum is quite convex forward. The neural arch is very broad at the base, the neural canal nearly circular, and the spine only a few millimeters in height. The vertebrarterial canal is elliptical, with the principal diameter about 8 mm. It was probably completely surrounded by bone when the vertebra was intact. It is situated a little below the middle of the height of the centrum.

4th Cervical (Pl. XIX, figs. 9, 10).—Only the imperfect centrum of this vertebra is preserved. The vertebrarterial canal appears to have been larger than in the 3d cervical.

5th Cervical (Pl. XIX, figs. 11, 12).—This vertebra is nearly complete. It is similar in form to the 3d, but the centrum is less convex anteriorly, and the neural canal depressed elliptical rather than round. The vertebrarterial canal was originally completely surrounded by bone, and had a diameter of about 11 mm. The outer slender portion of the ring was joined below to the superior edge of an oblong transverse process about 7 mm. long which extends obliquely downward and outward and a little backward.[1]

6th Cervical (Pl. XIX, fig. 13).—This vertebra is buried in the matrix under the 7th cervical in such a position that only the inferior transverse process, the ring around the vertebrarterial canal and the neural arch and spine can be seen. The inferior transverse process is large and inversely triangular, with the lower portion directed backward, so that it appears concave from behind. It is about 14 mm. long and 13 mm. broad at the top. The vertebrarterial canal is larger than in any of the preceding vertebræ and appears to have been completely

[1] The bony ring was traceable throughout while the vertebra lay in the matrix, but the parts became separated when it was removed and could not be reunited in the natural position. It is not shown, therefore, in Pl. XIX, fig. 11.

surrounded by a slender rod of bone. The diameter of the canal is about 14 mm. The neural spine is very short.

7th Cervical (Pl. XIX, fig. 13).—This vertebra has a long, slender and nearly straight superior transverse process, directed outward and a little downward. There is also a slender, curved inferior process about 11 mm. long directed obliquely outward and downward. The neural spine is but little longer than that of the 6th cervical; the neural canal elliptical.

Thoracics.

(Pl. XX, figs. 1–9; Pl. XXI, figs. 1–9; Pl. XXII, figs. 1–12.)

Nine thoracic vertebræ are preserved, including what appear to be the 1st and 3d. Five of them are nearly complete, and the remainder more or less broken, or represented only by upper or lower portions. They differ noticeably from the thoracics of many recent delphinoids and other odontocetes in that the neural spines are nearly vertical, instead of being strongly inclined backward. In this respect they resemble the vertebræ of *Phocæna* more closely than those of any other recent genus with which I am acquainted.

In the series of thoracics which has been preserved, the centra increase in length rapidly from the first to the third, and less rapidly, but still perceptibly, from that point backward. The metapophyses, from the 3d to the 7th thoracic, are short, thick, and nearly horizontal, with the articular facets for the ribs at first directed a little downward, but in the posterior vertebræ, outward. In the 1st thoracic (Pl. XXII, fig. 1), the metapophysis is broad and thin, and the articular facet for the first rib is directed obliquely downward.

The last three vertebræ in the thoracic series are badly broken, but one of them has the right transverse process intact. This is short, thick, and directed outward, and is situated so that its long axis is in line with the top of the centrum. It is not certain that these three vertebræ immediately follow the six preceding them, and hence is impossible to determine whether the situation of the articular facets for the ribs changes gradually from vertebra to vertebra as in recent delphinoids, or whether it changes abruptly at about the 8th thoracic from the side of the neural arch to the side of the centrum, as in *Berardius* and other recent ziphioids. Apparently it changes gradually, as in *Delphinus* and *Tursiops*.

The neural spines, as already mentioned, are nearly vertical, and hence, unlike those of many recent delphinoids. They resemble those of *Phocæna* among recent, and *Eurhinodelphis* among fossil forms. The spines of the more anterior vertebræ are nearly straight, and somewhat tapering, but those farther back are more or less recurved, especially at the tip.

The anterior zygapophyses are elliptical, nearly flat, and directed upward. The posterior zygapophyses are also elliptical and flat, and are directed downward.

The first six thoracics of the series at hand present facets on the postero-

superior lateral borders of the centra for the articulation of the heads of the ribs. The anterior and posterior faces of the centra of the 1st and 3d thoracics are elliptical, but those of the vertebræ farther back are cordate, or shield-shaped. The inferior surface of the centrum is rounded in the 1st and 3d thoracics, flat in the 4th, rounded in the 5th, and somewhat angular in the vertebræ farther back.

In addition to the foregoing general description, it seems desirable to record certain special features of individual vertebræ.

1st Thoracic (Pl. XX, fig. 1; Pl. XXI, fig. 1; Pl. XXII, figs. 1 and 7).—This vertebra has the general appearance of the seventh cervical of various recent delphinoids, but has a distinct facet for articulation of the tubercle of a rib. The centrum is about one-fourth as thick as broad, the anterior face concave and the posterior convex. The epiphyses are extremely thin, being scarcely more than 1 millimeter in thickness. There is a distinct oval facet for the articulation of the head of the second rib on the postero-superior lateral margin of the centrum. The neural arch is low, broad and quite thin, with a lateral process similar to itself on each side, which bears the facet for the articulation of the tubercle of the first rib. This facet is irregularly oval, and rather narrow. The anterior zygapophysis is elliptical, flat, very narrow, and directed upward. The posterior zygapophysis is similar but much larger, broader and concave, and is directed downward and a little inward. The spine is lacking, but was probably very short.

Compared with the same vertebra in *Phocæna*, the principal differences are as follows: The centrum is more distinctly elliptical. The neural canal is much larger. The neural arch and transverse process are broader, thinner and less elevated, and upper border of the latter becomes nearly vertical, instead of horizontal. The facet for the articulation of the tubercle of the rib is narrow and elongated and directed downward, while in *Phocæna* it is nearly round and directed outward. The posterior zygapophyses are directed downward, rather than obliquely outward.

3d Thoracic (Pl. XX, fig. 2; Pl. XXI, fig. 2; Pl. XXII, figs. 2 and 8).—This vertebra, with the epiphyses, is nearly half as thick as broad. The spine is erect and tapering and the metapophyses horizontal and directed a little forward, having a large oval articular facet at the end. Both anterior and posterior faces of the centrum are concave. This vertebra may possibly be the 2d thoracic, but as it does not fit well with the first, I am disposed to regard it as the third.

Compared with the same vertebra in *Phocæna*, the centrum is broader, more elliptical, and less elongated antero-posteriorly. The neural spine is vertical, instead of somewhat inclined backward.

4th Thoracic (Pl. XX, fig. 3; Pl. XXI, fig. 3; Pl. XXII, figs. 3 and 9).—The centrum of this vertebra, with the epiphyses, is more than one-half as long as broad. The anterior and posterior faces of the centrum are only slightly concave. The epiphyses are about 2 mm. thick. In most respects this vertebra is similar to the last. The spine, however, which is detached, appears to be a little recurved

at the tip, is much broader, antero-posteriorly, than that of the 3d thoracic. There is a distinct articular facet on the postero-superior lateral border of the centrum.

Compared with the same vertebra in *Phocæna* the centrum is larger, broader and shorter, and the epiphyses are shield-shaped, rather than rounded. The neural canal is much higher, and the transverse process much narrower, and not produced into a mammillary process at the extremity.

5th Thoracic (Pl. XX, fig. 4; Pl. XXI, fig. 4; Pl. XXII, figs. 4 and 10).—The centrum of this vertebra is much more than one-half as long as broad. The neural spine is erect and tapering, and recurved only at the tip, if at all. Otherwise, the vertebra closely resembles the last, but the metapophyses are broader, antero-posteriorly, and the inferior surface of the centrum is rounded, rather than flattened.

Compared with the same vertebra in *Phocæna*, the centrum is shorter and broader, the neural spine erected rather than inclined backward, and tapering rather than truncated at the extremity. The transverse process is much narrower, and not produced anteriorly at the extremity.

6th Thoracic (Pl. XX, fig. 5; Pl. XXI, fig. 6; Pl. XXII, figs. 6 and 12).—This vertebra lacks the neural spine and upper part of the arch. It differs but little from the last, except that the centrum is about as long as broad, that the metapophysis has a greater breadth antero-posteriorly.

7th Thoracic (Pl. XX, fig. 6; Pl. XXI, fig. 5; Pl. XXII, figs. 5 and 11).—This vertebra closely resembles the last, but the centrum is longer, and the metapophyses are slightly directed upward. The neural spine is somewhat recurved, and the tip distinctly so. The inferior surface of the centrum is somewhat angular.

This vertebra and the preceding one differ from those of *Phocæna* in the same manner as does the fifth. In the 7th the neural spine is tapering and recurved at the extremity, while in *Phocæna* the extremity is but little narrowed, and the posterior edge is nearly straight.

The three vertebræ which follow are probably separated by an interval of one or two from those already described, and are quite defective. The centra are longer than broad, and the epiphyses nearly circular. The inferior surface of the centrum, however, is angular. None of these three vertebræ has facets for the articulation of heads of ribs on the postero-superior lateral borders of the centrum.

Lumbars.

(Pl. XX, figs. 10–14; Pl. XXI, figs. 10–14; Pl. XXIII, figs. 1–6.)

Seven lumbar vertebræ are preserved, but all are incomplete, some lacking the neural arch and spine, and others part of the centrum or transverse processes. The centra are all longer than broad, and increase rapidly in length as well as in size from the anterior one backward. They have a very distinct median inferior

carina, with a thin free edge, the outline of which, when viewed from the side, is concave, especially in the vertebræ at the posterior end of the series. The under sides of the centrum are concave, and are traversed by very distinct oblique channels. The transverse processes are moderately long, very thin, nearly straight, and taper a little at the distal end. They are directed outward, with only a slight inclination backward.

The neural arch and spine are preserved only on one vertebra near the middle of the series. They are nearly vertical, but are slightly inclined backward. The arch is very broad antero-posteriorly, with concave anterior and posterior margins. The spine has a concave anterior border and convex posterior border. It is broader antero-posteriorly than the arch and expanded at the top, which is truncated obliquely, with the angles rounded. The metapophyses are situated a little nearer to the centrum than to the free end of the spine, and are directed obliquely upward and forward. They are irregularly elliptical in outline and thin. There are no distinct anterior or posterior zygapophyses.

The epiphyses of the lumbar vertebræ are comparatively thin, having a maximum thickness of about 4 mm.

The lumbars of the fossil form, as compared with those of *Phocæna*, have more elongated centra, and much broader neural spines, antero-posteriorly, while the metapophyses are larger and are directed obliquely upward, instead of extending horizontally forward. The transverse processes are, however, very similar in the two forms.

Caudals.

(Pl. XX, figs. 15–19; Pl. XXI, figs. 15–19; Pl. XXIII, figs. 7–11.)

Only five caudal vertebræ have been preserved. In three of them the transverse processes are perforated at the base by a vertical foramen, and, hence, they probably belong near the anterior end of the tail. The sides of the centra both above and below the transverse processes are concave. The postero-inferior facets for the articulation of the chevron bones are very prominent. The neural arch is strongly inclined forward. The spine is not preserved in any of the vertebræ. The transverse process in the most anterior caudal preserved is about as long as the centrum, quite thin, broad, and nearly straight. It is only slightly inclined backward and is rather expanded than tapering at the extremity, where the free margin is oblique and nearly straight. In one of the vertebræ in which the transverse process is perforated, this process is a little shorter than the centrum, thin, and very broad, with the anterior and posterior margins concave, and the extremity cut off obliquely, so that the anterior margin of the process is much longer than the posterior. The epiphyses of these vertebræ are nearly round, although the centra are distinctly quadrilateral, or irregularly pentagonal.

DIMENSIONS OF VERTEBRÆ.

Measurements.	Atlas.	Axis.	C. 3	C. 4	C. 5	C. 7
	mm.	mm.	mm.	mm.	mm.	mm.
Greatest height	65	70	49	——	48	51
Greatest breadth	76	79	46?	——	46+	[68]
Length of centrum	16[1]	19[3]	5	7	6	5?
Height of centrum	14	26	24	25	26	25
Breadth of centrum (anterior)	——	29[4]	28	[28]	27	27[4]
Height of neural canal (anterior)	38	27	21	——	16	18
Breadth of neural canal	33	21	21	——	24	21
Height of neural spine	5	16	2	——	3	6
Length of transverse process	16[2]	13	——	——	——	——

Measurements.	Th. 1 (A.)	Th. 3 (B.)	Th. 4 (C.)	Th. 5 (D.)	Th. 6 (E.)	Th. – (F.)	Th. – (G.)	Th. – (H.)	Th. – (I.)
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Greatest height	48+	85	92?	97	——	101	——	——	——
Greatest breadth	[72]	70	[61]	64	[70]	59	——	——	——
Length of centrum	9	14	17	20	24	24	26	30	36
Height of centrum	24	21	23	23	24	23	——	26	26
Breadth of centrum (anterior)	30	32	31	29	27	28	25?	[28]	27
Height of neural canal (anterior)	——	28	30	31	——	26	——	——	——
Breadth of neural canal	[26]	22	24	25	——	22	——	[18]	14
Height of neural spine	——	31	34?	39	——	45	——	——	——
Greatest diameter of articular facet for tubercle of rib	13	13	13	16	12	12?	——	12	——
Length of transverse process	——	——	——	——	——	——	——	16	——

Measurements.	L. – (A.)	L. – (B.)	L. – (C.)	L. – (D.)	L. – (E.)	L. – (F.)	Ca. 1 (A.)	Ca. – (B.)	Ca. – (C.)	Ca. – (D.)	Ca. – (E.)
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Greatest height	——	——	——	123?	——	100[6]	——	——	——	——	——
Greatest breadth	——	[141]	——	——	——	——	——	[108]	[100]	——	
Length of centrum	[39]	39	[39]	36?	[39]	41	[40]	40	36	[36]	[35]
Height of centrum	30	30	33	——	30	35	36	41[7]	42[7]	42[7]	42[7]
Breadth of centrum (anterior)	[32]	33	36	——	[32]	34	39	39	37[4]	40[4]	[42]
Height of neural canal (anterior)	——	——	24[4]	22[4]	30?[4]	24[4]	21[4]	——	11[4]	8[4]	7[4]
Breadth of neural canal	12	13	7	9	14	7	5	4	3	2	3
Height of neural spine	——	——	——	58[5]	——	44[6]	——	——	——	——	——
Length of transverse process	49?	53		——	51	——	——	36	29	——	——
Breadth of transverse process at base	23	22	21	——	20	19	——	21	21	——	——
Ditto at tip	——	12	——	——	14?	——	——	16?	26	——	——

CHEVRON BONES.

Three chevron bones have been preserved, which do not differ from those of recent delphinoids. One of them (*a*) is from an anterior caudal and is small, elongated and not deep. Another (*c*) which belongs farther back is larger, short and deep, with the inferior free margin expanded antero-posteriorly and projecting backward. The third (*b*) is intermediate between the other two,

[1] In median line below.
[2] From border of anterior articular facet of vertebra.
[3] Including odontoid.
[4] Posterior.
[5] Antero-posterior breadth at tip = 32 mm.
[6] The neural spine is a little defective at the extremity.
[7] Posterior, including facet for chevron.

differing from the last chiefly in the less extended and thicker inferior extremity. The dimensions are as follows:

Measurements.	*a*	*b*	*c*
	mm.	mm.	mm.
Greatest depth	13	28	27
Greatest breadth superiorly	14	10	12
Greatest breadth inferiorly	18	14	20
Distance between centers of articular facets	10	[14]	17

Ribs.

(Plate XXIV.)

The whole, or portions, of more than 21 ribs are preserved. The number of pairs originally present cannot be determined, but it exceeded eleven. The first eight pairs appear to have possessed both head and tubercle, as in many recent delphinoids.

Portions of both of the ribs belonging to the first pair are preserved. They are thin, broad and flat, and are somewhat tapering distally. One rib of the 2d pair is practically complete. This is a little thicker than the first one at the proximal end and nearly as broad. It tapers distally but is expanded again near the distal end and terminates in a thickened, oval facet for articulation with the sternal cartilage. The centers of the head and tubercle are separated by an interval of 24 mm. The third pair is similar to the second, but longer and more slender. The neck is shorter on each succeeding pair, and appears to end on the eighth pair, the posterior ribs having a single, large, rounded facet at the proximal end. Three such ribs belonging to the left side and one belonging to the right side have been preserved.

The dimensions of some of the ribs are as follows:

Measurements.	A. 1st Rib, Left.	B. 2d Rib, Left.	C. 3d Rib, Left.	D. 4th Rib, Right.	E. 5th Rib, Left.	F. —, Left.	G. —, Right.	H. —, Left.	I. —, Left.	J. —, Left.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Total length in a straight line	—	189	215	—	—	—	—	—	—	—
Greatest breadth at angle	18	17	14	—	11	9	9	9	8	10
Greatest breadth near middle of length	13	12	10	—	8	8	—	7	6	10
Greatest breadth at inferior extremity	—	15	14	—	—	—	—	—	—	—
Greatest breadth immediately above inferior extremity	—	18	15	—	15	—	—	—	—	—
Distance between centers of tubercle and head	—	24	22	24	22	21	20	12[1]	9[1]	7[1]
Greatest thickness of rib near the middle	3	3	3	—	4	4	—	5	5	4
Greatest thickness at the inferior extremity	—	8	8	—	5	—	—	—	—	—

Scapula.

The right scapula, which (except for a few fragments) is the only one preserved, is practically complete (Pl. XXV, fig. 1). It resembles that of *Inia* and

[1] Breadth of superior extremity.

Phocæna in that the coracoid and acromion are both directed downward; but, as will be shown below, this resemblance is probably illusive. The inferior border of the coracoid is nearly straight and descends from the border of the glenoid fossa. The process itself is oblong and scarcely at all expanded at the extremity. The acromion is similar in shape and of about the same length, but the extremity is rounded off. While this is its present form, it is evident, upon close examination, that the superior border is defective. There is a probability, therefore, that it had an ascending distal portion originally, as in *Sotalia* and many other recent delphinoids.

The posterior border of the scapula is deeply concave, and the superior border quite strongly and evenly convex with a perceptible dip anteriorly, while the anterior border is evenly, but not strongly, concave. The even convexity of the superior border is doubtless partly due to immaturity. The internal surface of the scapula shows scarcely any trace of ridges and depressions, while the external surface is hidden in the matrix.

The dimensions of the scapula are as follows: Length of superior border, 163 mm.; height above glenoid fossa, 103; length of acromion (imperfect), 34; length of coracoid process, 28.

Pectoral Limb.

The bones of the pectoral limb, as a whole, are quite unlike those of typical recent delphinoids, and remind one rather of *Inia*, *Eurhinodelphis*, and *Berardius*, though differing from any of these.

Humerus (Pl. XXV, fig. 2).—The humerus is as long as the radius. It is irregularly concave on the upper (or posterior) border, and irregularly convex on the lower (or anterior) border, and the outline of the internal face is strongly concave. The head is large and placed obliquely. The greater tubercle is scarcely visible over the condyle when the humerus is viewed from in front, but when viewed from the side it is seen that it is a very little higher than the condyle. The bicipital groove is broad and very shallow. The deltoid ridge is but little salient, being represented rather by a large, low, elliptical swelling on the border of the shaft. There is a similar, but smaller and more angular protuberance on the upper (or posterior) border of the shaft. The external surface is marked by a deep pit, situated nearer the proximal than the distal end. The articular facets for the radius and ulna are very distinct, but form only a slight angle with one another. The ulnar facet extends some distance up the upper border of the ulna.

Radius (Pl. XXV, fig. 3).—The radius is strongly curved, rather flat, and a little more expanded and thinner at the distal end than at the proximal end. The lower (or anterior) border is strongly convex, and the upper (or posterior) border, strongly concave. It follows from this, and the fact that the ulna has curved margins, that there is a large elliptical vacant space between the two bones, which in ordinary recent delphinoids are in contact.

Ulna (Pl. XXV, fig. 4).—The ulna is more slender than the radius. It is straight, but greatly expanded distally and somewhat so proximally, which

causes the borders to be concave. The distal end is nearly transverse, but somewhat rounded, and is narrowly oval in section and thinner than the distal end of the radius. The proximal end is convex and is joined by a large, erect, lunate olecranon, unlike anything found in the recent delphinoids, and reminding one rather of the ziphioids. The peculiar characteristics of the limb-bones above described, when taken together, differentiate this species from any hitherto known.

The epiphyses of the humerus are detachable, the proximal one being very thick, and the distal one thin, especially on the radial side.

Only one small, elliptical carpal bone has been preserved and none of the phalanges.

The dimensions of the bones of the pectoral limb are as follows:

Humerus.—Total length, 67 mm.; greatest breadth at proximal end, 40; greatest breadth at distal end, 30; greatest breadth across middle of shaft, 29; diameter of head, 24; least thickness of shaft, 16; thickness at distal end, 18.

Radius.—Length between centers of opposite extremities, 59; breadth at proximal end, 24; breadth at distal end, 28; least breadth at middle, 18; thickness at proximal end, 15; thickness at distal end, 12.

Ulna.—Length, exclusive of olecranon, 58; breadth at proximal end, exclusive of olecranon, 13; breadth at distal end, 24; least breadth of shaft, 12; thickness at proximal end, 12; thickness at distal end, 10; length of olecranon, 23; breadth of olecranon, 14; height of olecranon above proximal end of ulna, 15.

Nomenclature.

It is a matter of much difficulty to decide what name should be applied to the specimen described in the foregoing pages. Numerous species of American fossil cetaceans were based by Leidy, Cope and other authors on single teeth, a vertebra or two, and the like, and unless one has material in hand which is strictly comparable it is not easy to reach a conclusion as to whether the differences observable are of specific importance, or due to age, individual variation, etc. In looking over the type-specimens of American species, I have found one tooth which shows a close similarity to those of the form herein described. This tooth was from the Miocene of Virginia, and was described by Leidy in 1856, under the name of *Phoca wymani*, which name Leidy in 1854 applied, without description, to the fragment of a skull of a seal made known by Wyman in 1850, but not named. In 1867, Cope added a description of three additional teeth from Charles County, Maryland, under the name of *Squalodon wymani*, and also described a second species, under the name of *Squalodon mento*, based on four teeth from Charles County. In 1869, Leidy established the new genus *Delphinodon* for these two species and included them, with various squalodont and zeuglodont forms, under the ordinal name of Zeuglodontes, but without assignment to any family. Since that date the genus *Delphinodon* has been variously assigned to the Squalodontidæ, Platanistidæ, etc., but usually to the former family.

In 1902, Dr. O. P. Hay pointed out the fact that the name *Phoca wymani* really belonged to the seal skull originally described by Wyman in 1850, and could not properly be applied to the teeth from Virginia and Maryland. He renamed the latter *Delphinodon leidyi*, designating as the type-specimen the tooth figured by Leidy in 1869, in the *Extinct Mammalian Fauna of Dakota and Nebraska*, Pl. 30, fig. 12. Though this change of name is very unfortunate, in view of the fact that the species has become imbedded in the literature under the designation of *wymani*, it seems unavoidable under the rules generally adopted to-day. Dr. Hay also, in 1902, fixed upon *D. mento* as the type of the genus *Delphinodon*.

The type-tooth of *Delphinodon leidyi*, as already mentioned, presents a close similarity to those of the form herein described. It seems to leave no room for doubt that the two forms belong to the same genus, and this conclusion involves the corollary that the genus *Delphinodon*, or at least the species *D. leidyi*, belongs to the family Delphinidæ. This will be more fully considered under the next heading.

Whether the present form is identical specifically with *D. leidyi* is more difficult to determine. The type-tooth of the latter species is in the museum of The Academy of Natural Sciences of Philadelphia, where it was examined recently by myself. This tooth agrees almost exactly in form with the right lower tooth No. 2 of the Chesapeake Beach skeleton herein described. It has the same ridges in the same relative positions. The crown is flattened anteriorly and posteriorly in similar fashion in both teeth. The antero-exterior ridge bifurcates in the same manner in both teeth and at about the same point, relatively, but the angle of divergence is greater in the type-tooth of *D. leidyi*.

The main differences between the two teeth mentioned above are that the type-tooth of *D. leidyi* is a little larger than that from the Chesapeake Beach skeleton, the crown is rather more incurved, and the posterior branch of the bifurcated antero-external ridge is more prominent and more distinctly crenulated.

In the type-tooth of *D. leidyi* the root is nearly or quite closed below, indicating that it is from an adult individual. The longitudinal furrow shown in Leidy's figure of this tooth, pl. 30, fig. 12, is not a groove but a crack which extends through the crown as well as the root. The little rugosities seen at the upper right edge of the crown in Leidy's figure are part of the external ridge. The protuberance at the lower left edge is a part of the cingulum from which the internal ridge springs. The ridge itself is represented by the dark line on that side of the figure. The figure as a whole is not accurate. The root is made to appear too flat, being in reality quite convex, and is curved backward at the lower end. The enamel of the crown of this tooth is everywhere rugose, except as affected by wear, and the rugosity is a little more pronounced than in the tooth from the Chesapeake Beach skeleton with which it has been compared above.

The three additional teeth from Charles County, Maryland, which were

referred to *D. wymani* (= *D. leidyi*) by Cope are also in the Academy's collection. There is no apparent reason for disputing the correctness of this assignment, although these specimens differ in various details from the type-tooth. The one figured by Leidy in pl. 30, fig. 10, is extremely similar to the lower left tooth No. 3 of the Chesapeake Beach skeleton, but is much larger and has the postero-internal ridge much more pronounced and distinctly crenulated, or tuberculated. This gives the former tooth the breadth shown in Leidy's figure. Otherwise, in its curvature, in the position of the ridges, in the rugosity of the enamel, etc., the two teeth are practically identical. In Leidy's fig. 10 the antero-external ridge is on the left margin of the dark oblong fracture and above the latter it forms the outline of the crown.

The tooth shown in Leidy's fig. 11, which is another of the Charles County teeth assigned to *D. leidyi* by Cope, shows distinct traces of anterior and posterior longitudinal ridges, but the enamel is worn nearly smooth.

Another of these Charles County teeth exhibits traces of the postero-internal ridge, but not of the antero-external one, and the enamel is worn quite smooth. This tooth and the preceding one look a little more massive than the type and the tooth represented in Leidy's fig. 10, but they have the crowns blackish like the type.

A tooth in the National Museum which was picked up from the shore at Chesapeake Beach, and is numbered 1118, is almost a duplicate of the type of *D. leidyi*, but from the opposite side of the mouth. The crown is a little shorter and the root a little thicker and the antero-external ridge more strongly crenulated. The latter is apparently not bifurcated, but as the enamel is worn nearly smooth this cannot be determined accurately. There is a slight constriction at the upper end of the root in the type-tooth of *D. leidyi* which is not found in the other tooth, but this appears to be due to wear.

The National Museum collection contains another tooth from Chesapeake Beach (in vial marked 1244–1247) which is almost the exact counterpart of Leidy's fig. 10. The ridges are the same and in the same positions, but the tuberculation of the postero-internal ridge is worn away and that of the antero-external ridge is very indistinct. The two teeth mentioned are practically identical in size.

DIMENSIONS OF TEETH OF *Delphinodon leidyi*.

Measurements.	Type. Miocene of Virginia. Leidy, pl. 30, fig. 12.	Charles Co., Maryland. Leidy, pl. 30, fig. 10.	Charles Co., Maryland. Leidy, pl. 30, fig. 11.	Charles Co., Maryland. Third Tooth.	U. S. N. M. No. 1118. Chesapeake Beach, Md.	U. S. N. M. No. 1244–1247. Chesapeake Beach, Md.
	mm.	mm.	mm.	mm.	mm.	mm.
Total length	30.0	28.0[1]	33.0	38	30.5	24.2[1]
Length of crown	9.0	10.0	10.0	10	9.2	9.4
Greatest diameter of crown at base	7.0	8.5	8.0	8.5	6.5	7.0
Greatest diameter of root	6.5	7.0	8.0	7.0	5.9	6.4
Diameter of root at lower extremity	3.5	4.0	4+	2.5	2.4	3.0

[1] Root defective.

In the foregoing table are given the dimensions of the type and other teeth of *D. leidyi* in The Academy of Natural Sciences of Philadelphia and of the two detached teeth from Chesapeake Beach above mentioned.

The average diameter of these six teeth at the base of the crown is 7.6 mm., while the average for 42 teeth from the Chesapeake Beach skeleton is 5.2 mm. The average maximum diameter of the root in the six teeth of *D. leidyi* is 6.8 mm. and in 38 teeth from the Chesapeake Beach skeleton, 5.3 mm. This marked difference in the size of the teeth can hardly be regarded as due to the difference in age which is observable, or to individual variation. The roots might, and probably would, increase in diameter with age, owing to the deposit of cement, but the same cannot be said of the crowns. The conclusion seems inevitable, therefore, that the Chesapeake Beach skeleton represents a species allied to *Delphinodon leidyi*, but having smaller teeth. If this be correct, it would, of course, be expected that *D. leidyi*, when better known, would be found to possess various osteological characters which would render it distinguishable from the Chesapeake Beach species herein described. It seems best, under the existing circumstances, to regard the latter as a separate species, and a diagnosis of it and of the genus *Delphinodon*, to which it is supposed to belong, are appended.

Genus **DELPHINODON** Leidy. (Emended.)

Skull broad and depressed. Rostrum short, triangular. Premaxillæ broad and flat on the sides and in front of the nares and extending backward to the sides of the nasals. Nasals oblong, directed forward. Free margin of the orbital plate of the maxillæ thin. Symphysis of the mandible long.

Posterior teeth with distinct accessory cusps, and crowns of all the teeth with rugose enamel, and anterior and posterior longitudinal ridges, the former more or less bifurcated at the base.

Cervical vertebræ all separate. The atlas with a single transverse process on each side, a complete foramen for the exit of the first spinal nerve, and an inferior median facet for articulation with the odontoid process of the axis. Third to sixth cervicals with the vertebrarterial foramen completed surrounded by bone. Spines of thoracic vertebræ erect. Lumbars moderately elongated, their transverse processes narrow, and tapering at the extremity. More than eleven pairs of ribs; the anterior pairs with both head and tubercle.

Humerus elongated, with a distinct pit on the outer side of the shaft. Radius strongly curved. Ulna with a large, lunate olecranon.

Delphinodon dividum new species.

Size small. Rostrum of the skull a little more than one-half the total length. Symphysis of the mandible about one-third the total length of the latter. Premaxillæ opposite the nares about as wide as the portion of the orbital plate of the maxillæ external to them. Nasals oblong, with the anterior surface concave. Vomer visible near the middle of the palate, in the form of a short, broad lozenge.

Palatines in contact in the median line throughout their length; their surface concave posteriorly. Descending wings of the basi-sphenoid with a strong transverse ridge.

Teeth about $\frac{27-27}{26-26}$, small, with an average diameter at the base of the crown of 5.2 mm., and total length about 29 mm.; more or less flattened anteriorly and posteriorly. Crowns short and strongly recurved, especially near the posterior end of the series. Last superior tooth with two accessory cusps behind the main cusp. Other posterior teeth with an accessory cusp on each side of the main one, and a bifurcated antero-external longitudinal ridge, and simple postero-internal ridge.

Type-specimen: Cat. No. 7278 U. S. Nat. Mus. Skeleton from the Calvert Cliffs, Chesapeake Bay, Maryland, one mile south of Chesapeake Beach. Collected May 30, 1908, by William Palmer. Preserved in the U. S. National Museum.

Relationships.

The remarkable fossil remains described above throw a strong light on the origin of the existing typical dolphins. There can be no doubt that the genus belongs to the family Delphinidæ, but it is distinguished from all others of that family in that the posterior teeth are distinctly tuberculate.

The Delphinidæ, as is well known, are characterized by the numerous teeth in both jaws, very broad occipital region, conjoined lachrymal and malar bones, inflated pterygoid bones, broad and rather flat frontal plates of the maxillæ, slightly concave prenarial region (typically), anchylosed atlas and axis (the former with a single transverse process), anterior ribs with both tubercle and neck, ossified sternal ribs.

The form under consideration presents most of these characters, the deviations therefrom being chiefly such as one would expect to find in a primitive form. Thus, the atlas and axis are separate, but when placed in contact it is seen that they present the same general form as the conjoined bones of recent species. The pterygoid bones are lacking in the specimen described, as is usually the case with fossil skulls of cetaceans, but the impressions remaining indicate that they had the same general form as those of recent delphinoids. The sternal ribs are also lacking, having no doubt remained cartilaginous owing to the immaturity of the individual.

The most striking primitive characters of the species are the rugosity of the enamel layer of the teeth and the presence of anterior and posterior ridges and accessory cusps. The teeth of recent typical delphinoids, with the exception of *Steno*, have smooth crowns. In *Steno* the rugosity is distinguishable with the naked eye, and under a glass it is seen also that the majority of the teeth have anterior and posterior ridges, which extend downward from the apex at least to the middle of the crown. This peculiarity in a genus which otherwise presents the characters of a typical delphinoid, is extremely interesting, and points to affinity with the fossil genus. Accessory cusps, or tubercles, are not observable

in *Steno*, but were recently noticed by myself, and confirmed by Lönnberg, in *Delphinapterus*.

The skull somewhat resembles that of *Phocæna*, especially in the nearly vertical position of the nasal bones and the thinness and flatness of the orbital plates of the maxillæ and frontals. It presents a marked difference, however, in that the premaxillæ are broad and flat, or a little concave, in front of the nares, and extend backward to the outer side of the nasals. In its general conformation, the skull presents a close resemblance to *Sotalia*, but in the latter genus the orbital plate of the maxillæ is thickened anteriorly and strongly bent upward posteriorly, while the nasals are placed high and directed upward rather than forward. The vertical position of the nasals in the fossil form and their slight projection over the nares should probably be regarded as a primitive character rather than as indicating any close affinity to *Phocæna*.

The symphysis of the mandible, which is short in most recent delphinoids, is long in the present genus. Taken alone, this character cannot, in my opinion, be regarded as indicating an affinity with the recent and fossil inioid dolphins, platanistids, or eurhinodelphoids, especially in view of the fact that in the recent delphinoid genus *Steno* the symphysis is also long.

The earbones are typically delphinoid, and differ from those of *Phocæna* chiefly in proportions, but it must be remembered that those of *Squalodon* are not very different from the former. The form of the hyoid is also delphinoid.

The separation of the atlas and axis naturally reminds one of such genera as *Prosqualodon*, *Eurhinodelphis*, *Inia*, *Delphinapterus*, *Monodon*, *Platanista*, etc. In all but the last two, however, there are two transverse processes on each side instead of a single one. *Monodon* also presents rudiments of a second process, and *Platanista* is too far removed from the present genus in other respects to merit attention in this connection.

The erect neural arch and spine of the thoracic vertebræ of the present genus find a counterpart in *Phocæna*, among recent delphinoids. They remind one also of the same parts in the genera *Eurhinodelphis* and *Prosqualodon*. The lumbars and caudals resemble those of delphinoids, in contradistinction to the ziphioids, physeteroids, etc.

The scapula presents a resemblance to that of *Inia*, but as previously remarked (p. 184) this is probably due to the incompleteness of the acromion, which in its original form is quite likely to have had the form characteristic of the delphinoid genera. The humerus, though longer proportionately than in most recent dolphins, is essentially of the same form as in those genera. It cannot be denied, however, that the rather high larger tuberosity reminds one of *Eurhinodelphis*, while the straight shaft is not unlike that of *Berardius*. The radius is more curved than in modern delphinoids, and the ulna more slender, while the large open space between them is not characteristic of that group, but rather of various genera in other groups, such as *Berardius*, *Inia*, *Platanista*, *Physeter*, etc. The olecranon of the ulna is of a peculiar lunate form, resembling that of the ziphioids *Berardius* and *Ziphius*, rather than the delphinoids.

Among fossil genera already known, the present form most closely resembles *Heterodelphis*. It might, indeed, probably be included in that genus, except that in the latter the mandible has a longitudinal furrow on each side, and the teeth have long, slender and smooth crowns. Two species of *Heterodelphis* have been described—*H. klinderi* Brandt and *H. leiodontus* Papp. The figures of the former published by Brandt[1] are extremely unsatisfactory, while those of *H. leiodontus* published by Papp[2] show that the specimen on which the species was based was so badly broken that scarcely any character is clearly determinable. From Brandt's figures of *H. klinderi*, however, we learn that that species is somewhat smaller than the present form and that the atlas has a more pronounced median basal facet for the odontoid, and a more descending transverse process. The posterior cervicals are of about the same form, though smaller. The thoracics and lumbars, on the other hand, differ noticeably in that the transverse processes are expanded, as in *Inia*. The scapula differs widely in form, but it is hardly probable that the figure is accurate. The humerus is similar in general form, but more expanded below. This figure, like the preceding, is probably inaccurrate.

The tympanic bone is apparently broad at the anterior end as in the present form.

The differences between *H. leiodontus* and the present form have been already mentioned. Among the similarities may be mentioned the form of the atlas, which has complete foramina in the sides of the neural arch for the exit of the first pair of spinal nerves and a short, triangular transverse process. The vertebræ appear to be quite similar in the two forms except that the neural spines of the anterior thoracics are strongly inclined backward, as in *Tursiops* and some other recent delphinoids. The scapula appears to be quite similar in form. The correspondence of the humerus, radius and ulna is very striking, but the major tuberosity of the humerus appears to be higher in *H. leiodontus* than in the present form and the deltoid ridge, or tuberosity, more salient. The radius is less curved in the former but the ulna appears to have presented indications of the same lunate olecranon found in the present species.

Dr. Papp convinced himself that *H. leiodontus* was a very long beaked dolphin, with 60 teeth or more on either side of each jaw.[3] I do not find anything in the figures or description, however, inconsistent with the view that the rostrum was about as long as in *Delphinodon*, that the symphysis of the mandible was about one-third the total length of the latter, and that the teeth were about 38 on either side of each jaw.

Dr. Papp assigned the genus *Heterodelphis* to the family Platanistidæ,[4] while Brandt in 1873 had assigned it to the Delphinidæ[5] and Dr. Abel, in 1905, to the Acrodelphidæ (= Iniidæ).[6]

[1] Mém. Acad. Imp. St. Pétersb., ser. 7, XX, 1873, pls. 25, 26.
[2] Mitt. Jahrb. kgl. ungar. geol. Anst., XIV, 1902–6, pp. 23–62, pls. 5, 6.
[3] L. c., pp. 49 and 52.
[4] L. c., p. 60.
[5] Mém. Acad. Imp. Sci. St. Pétersb., ser. 7, XX, 1873, pp. v, vi, 226 and 248.
[6] Mém. Mus. Roy. Hist. Nat. Belg., III, 1905, p. 120.

In my opinion, Brandt's classification is the correct one.

I am convinced also that *Delphinodon* belongs to the Delphinidæ. We have, therefore, two distinctive fossil representatives of this family, besides *Pithanodelphis* Abel (1905), *Delphinopsis* Müller (1853), and the phocænids *Protophocæna* and *Palæophocæna* Abel.

In the present form we have, in my opinion, one of the progenitors of the recent Delphinidæ. We learn from it that these dolphins were derived from forms having teeth with crowns rugose and possessing three or more cusps, and anterior and posterior ridges; the rostrum with a wide median interspace between the premaxillæ; and separate cervical vertebræ with complete vertebrarterial foramina—the atlas with a complete foramen in the neural arch for the exit of the first spinal nerve.

The rugosity of the enamel of the teeth and the anterior and posterior ridges are still retained in the recent genus *Steno*, while both that genus and *Sotalia* have a rather wide interspace between the premaxillæ. These characters are also shared by the fossil genus *Squalodon*, but, in my opinion, it does not necessarily follow that the delphinoids are derived from the squalodonts, although the presumption is very strong in that direction. There are certain difficulties which cannot be ignored. In the squalodont genera *Prosqualodon* and *Diochotichus*, there are two transverse processes on each side of the atlas, while in the delphinoid genera (the atypical *Delphinapterus* excepted) there is but one. It is difficult to see exactly how the serrate crowns of the teeth of typical squalodonts could be transformed into the trituberculate crowns of *Delphinodon*. The anterior and posterior longitudinal ridges do not represent a modification of the squalodont cusps, because in *Delphinodon* the ridges and cusps, or tubercles, are both present, the former running quite across the latter. Still, as certain forms of *Acrodelphis* which may reasonably be considered as derived from the squalodonts have teeth which present modifications of those of the latter group, it is no doubt allowable to suppose that the teeth of *Delphinodon* may have had a similar origin, or in other words, that it is derived from squalodontoid ancestors. If such has been the fact, it is presumable that the delphinoid was not derived directly from *Squalodon*, *Prosqualodon*, or their allies, but from other parallel forms of a somewhat earlier age. The resemblance of the teeth of *Delphinodon* to those of certain seals, such as *Halichœrus*, is very striking, and it is not to be wondered at that Leidy and other zoologists considered them at first as belonging to pinnipeds. No one will suppose, however, that there is any direct connection between the latter and the delphinoid cetaceans.

EXPLANATION OF PLATES XVII–XXVI.

PLATE XVII.

FIG. 1. Skull, superior aspect.
FIG. 2. Skull, inferior aspect.
FIG. 3. Skull, lateral aspect.
A little more than one-half natural size.

PLATE XVIII.

FIG. 1. Skull, posterior aspect.
FIG. 2. Mandible, right ramus, exterior.
FIG. 3. Mandible, left ramus, interior.
FIG. 4. Mandible, superior aspect.
About one-half natural size.

PLATE XIX.

FIG. 1. Lower teeth. Natural size.
FIG. 2. Upper teeth. Natural size.
FIG. 3. Atlas, anterior aspect.
FIG. 4. Atlas, posterior aspect.
FIG. 5. Axis, anterior aspect.
FIG. 6. Axis, posterior aspect.
FIG. 7. Third cervical vertebra, anterior aspect.
FIG. 8. Third cervical vertebra, posterior aspect.
FIG. 9. Fourth cervical vertebra, anterior aspect.
FIG. 10. Fourth cervical vertebra, posterior aspect.
FIG. 11. Fifth cervical vertebra, anterior aspect.
FIG. 12. Fifth cervical vertebra, posterior aspect.
FIG. 13. Sixth and seventh cervical vertebræ in the matrix, anterior aspect.
Figures of vertebræ about seven-tenths natural size.

PLATE XX.

FIGS 1 to 9. Thoracic vertebræ, lateral aspect. Fig. 1, first; fig. 2, third; fig. 3, fourth; fig. 4, fifth; fig. 5, sixth; fig. 6, seventh.
FIGS. 10–14. Lumbar vertebræ, lateral aspect.
FIGS. 15–19. Caudal vertebræ, lateral aspect. Fig. 15, first caudal.
About two-thirds natural size.

PLATE XXI.

FIGS. 1– 9. Thoracic vertebræ. (Fig. 5 should stand behind fig. 6 instead of in front of it.)
FIGS. 10–14. Lumbar vertebræ.
FIGS. 15–19. Caudal vertebræ.
Superior aspect. About seven-tenths natural size.

PLATE XXII.

FIGS. 1– 6. Thoracic vertebræ, anterior aspect.
FIGS. 7–12. Thoracic vertebræ, posterior aspect. Figs. 1 and 3, first; figs. 2 and 8, third; figs. 3 and 9, fourth; figs. 4 and 10, fifth; figs. 5 and 11, seventh; figs. 6 and 12, sixth.
About seven-tenths natural size.

PLATE XXIII.

FIGS. 1– 6. Lumbar vertebræ, anterior aspect.
FIGS. 7–11. Caudal vertebræ, anterior aspect.
About seven-tenths natural size.

PLATE XXIV.

Ribs. About two-thirds natural size.

PLATE XXV.

FIG. 1. Right scapula, internal surface.
FIG. 2. Left humerus, external surface.
FIG. 3. Radius.
FIG. 4. Ulna.
FIG. 5. Hyoid bones.
FIG. 6. Left periotic bone, internal aspect.
FIG. 7. Left periotic bone, external aspect.
FIGS. 8–11. Two other periotic bones of the same species, from Chesapeake Beach. More or less water-worn.
FIG. 12. Right tympanic bone. Inferior aspect.
FIG. 13. Right tympanic bone. Exterior aspect.
FIGS. 14–17. Other fragmentary tympanic bones of the same species, from Chesapeake Beach. Water-worn.
Figs. 1–4, about seven-tenths natural size; fig. 5, about two-thirds natural size; figs. 6–17, natural size.

PLATE XXVI.

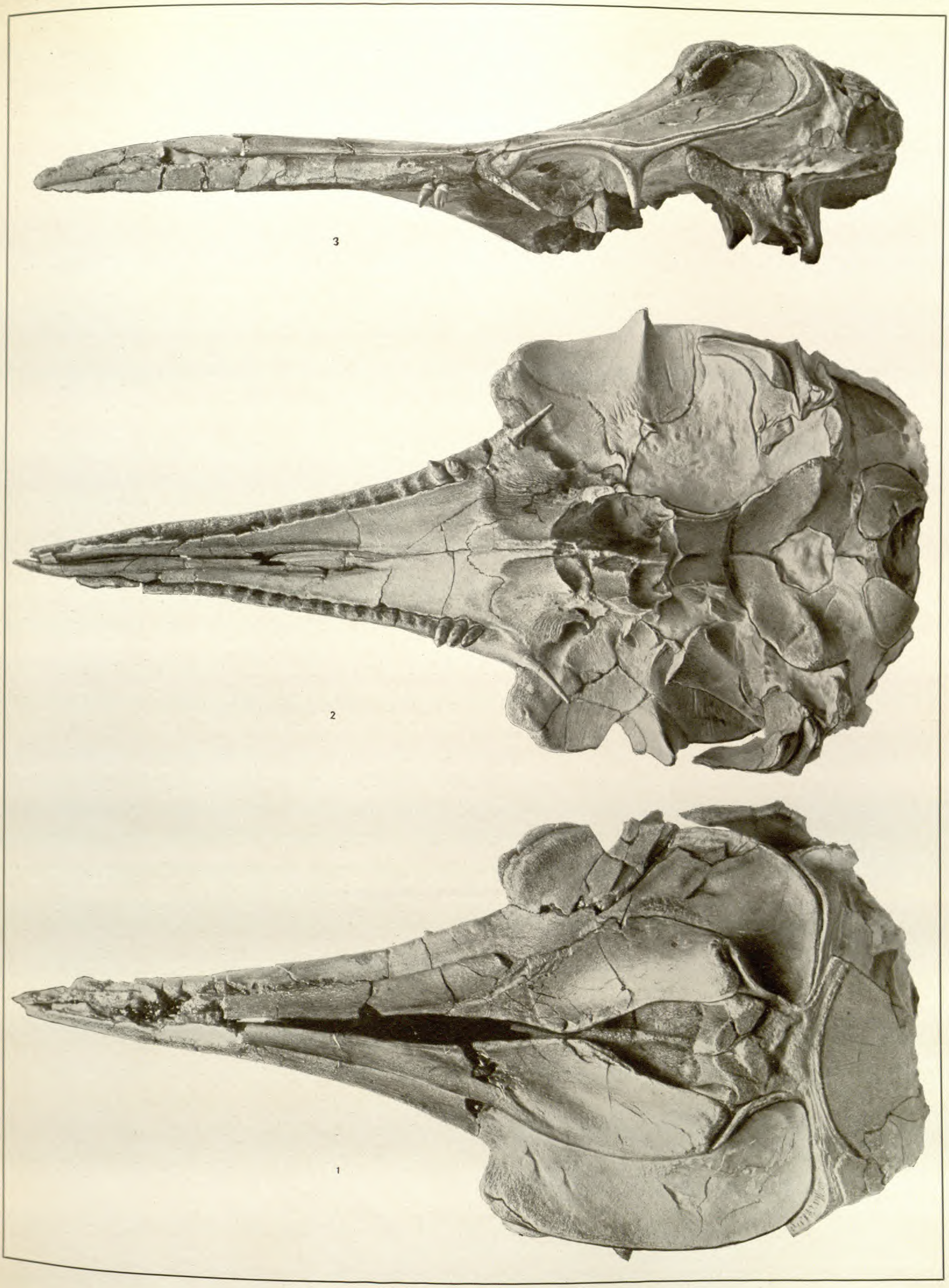
FIGS. 1–20. Teeth (numbered to agree with the enumeration of detached teeth at the top of the table of measurements on pp. 173, 174).

FIG. 1. Lower left, No. 1.
FIG. 2. Lower left, No. 2.
FIG. 3. Lower left, No. 2.
FIG. 4. Lower left, No. 6.
FIG. 5. Lower left, No. 1.
FIG. 6. Lower left, No. 2.
FIG. 7. Lower left, No. 3.
FIG. 8. Lower right, No. 5.
FIG. 9. Lower left, No. 6.
FIG. 10. Lower right, No. 3.
FIG. 11. Lower right, No. 5.
FIG. 12. Lower left, No. 3.
FIG. 13. Lower right, No. 3.
FIG. 14. Upper right, No. 1.
FIG. 15. Upper right, No. 4.
FIG. 16. Upper right, No. 6.
FIG. 17. Upper right, No. 1.
FIG. 18. Upper right, No. 4.
FIG. 19. Upper right, No. 6.
FIG. 20. Upper right, No. 7.

All figures 2½ times natural size.

PLATE XVII.

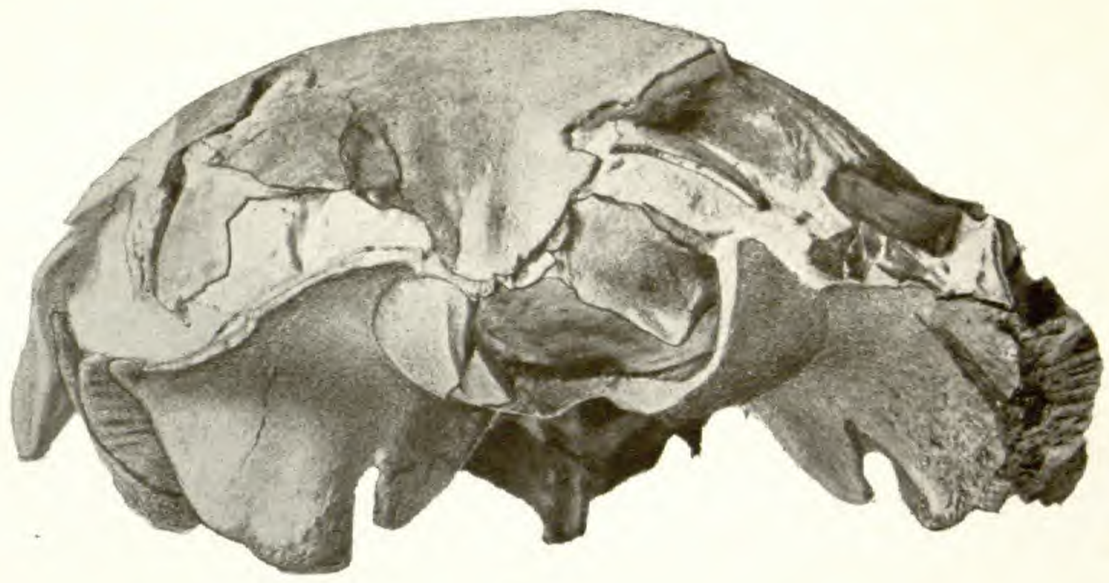
FIG. 1. Skull, superior aspect.
FIG. 2. Skull, inferior aspect.
FIG. 3. Skull, lateral aspect.
A little more than one-half natural size.



TRUE: DELPHINODON DIVIDUM

PLATE XVIII.

FIG. 1. Skull, posterior aspect.
FIG. 2. Mandible, right ramus, exterior.
FIG. 3. Mandible, left ramus, interior.
FIG. 4. Mandible, superior aspect.
About one-half natural size.



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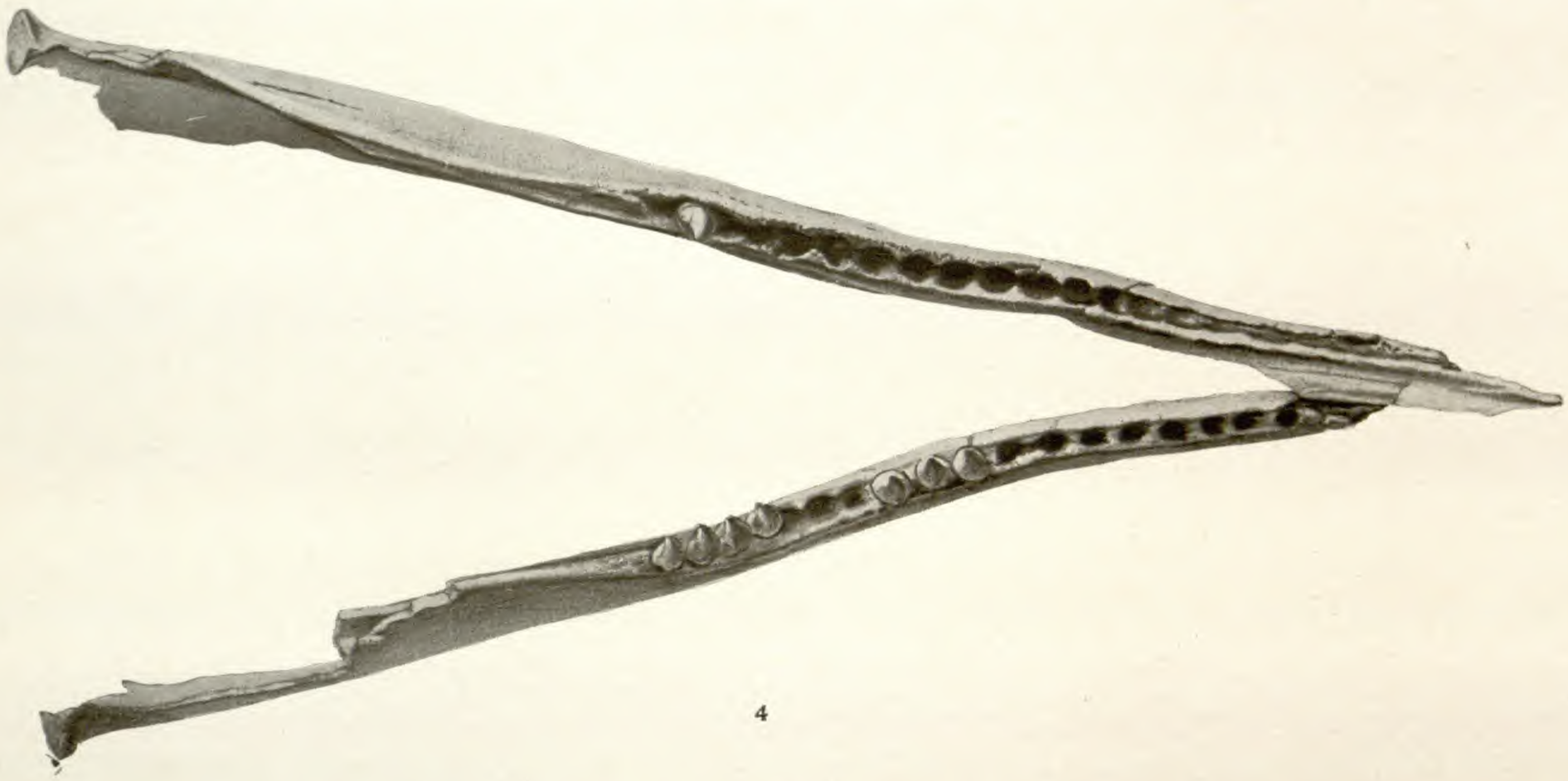

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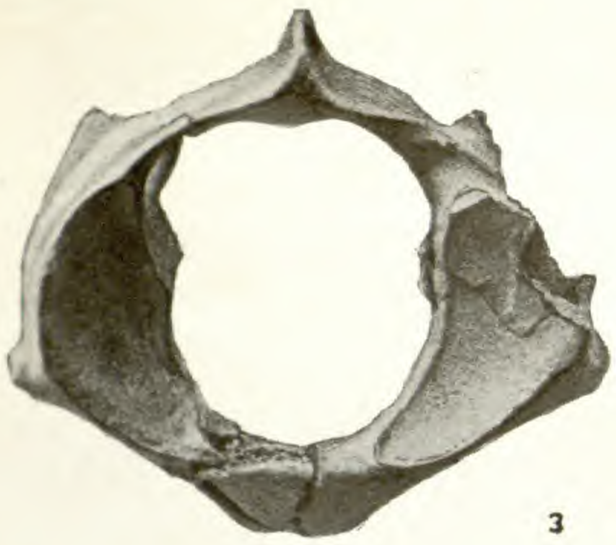
TRUE: DELPHINODON DIVIDUM

PLATE XIX.

FIG. 1. Lower teeth. Natural size.
FIG. 2. Upper teeth. Natural size.
FIG. 3. Atlas, anterior aspect.
FIG. 4. Atlas, posterior aspect.
FIG. 5. Axis, anterior aspect.
FIG. 6. Axis, posterior aspect.
Fig. 7. Third cervical vertebra, anterior aspect.
FIG. 8. Third cervical vertebra, posterior aspect.
FIG. 9. Fourth cervical vertebra, anterior aspect.
FIG. 10. Fourth cervical vertebra, posterior aspect.
FIG. 11. Fifth cervical vertebra, anterior aspect.
FIG. 12. Fifth cervical vertebra, posterior aspect.
FIG. 13. Sixth and seventh cervical vertebræ in the matrix, anterior aspect.
Figures of vertebræ about seven-tenths natural size.



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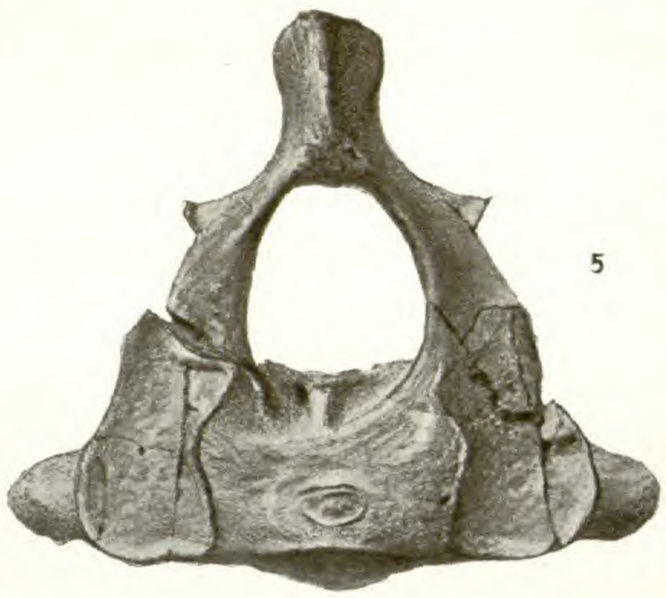

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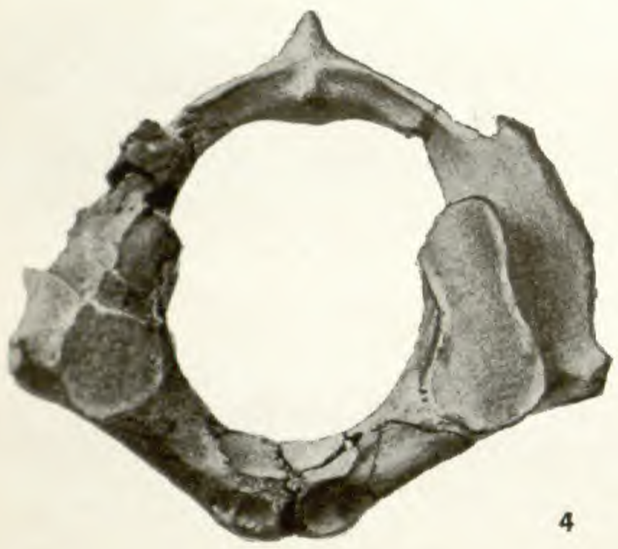

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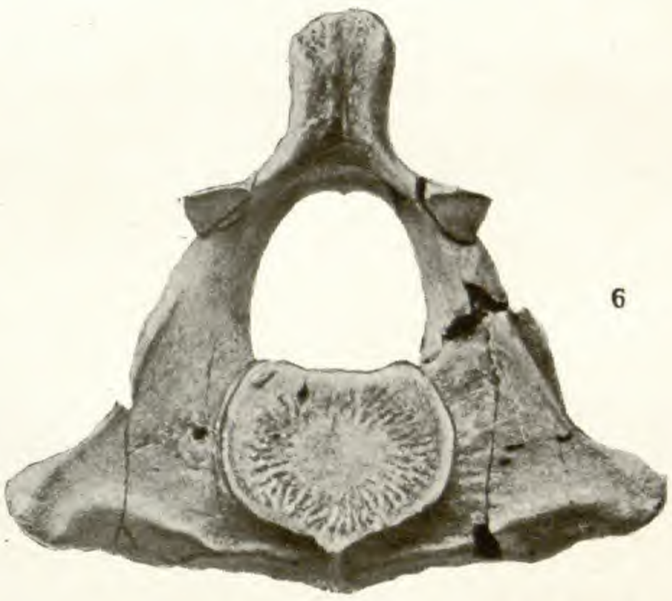

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TRUE: DELPHINODON DIVIDUM

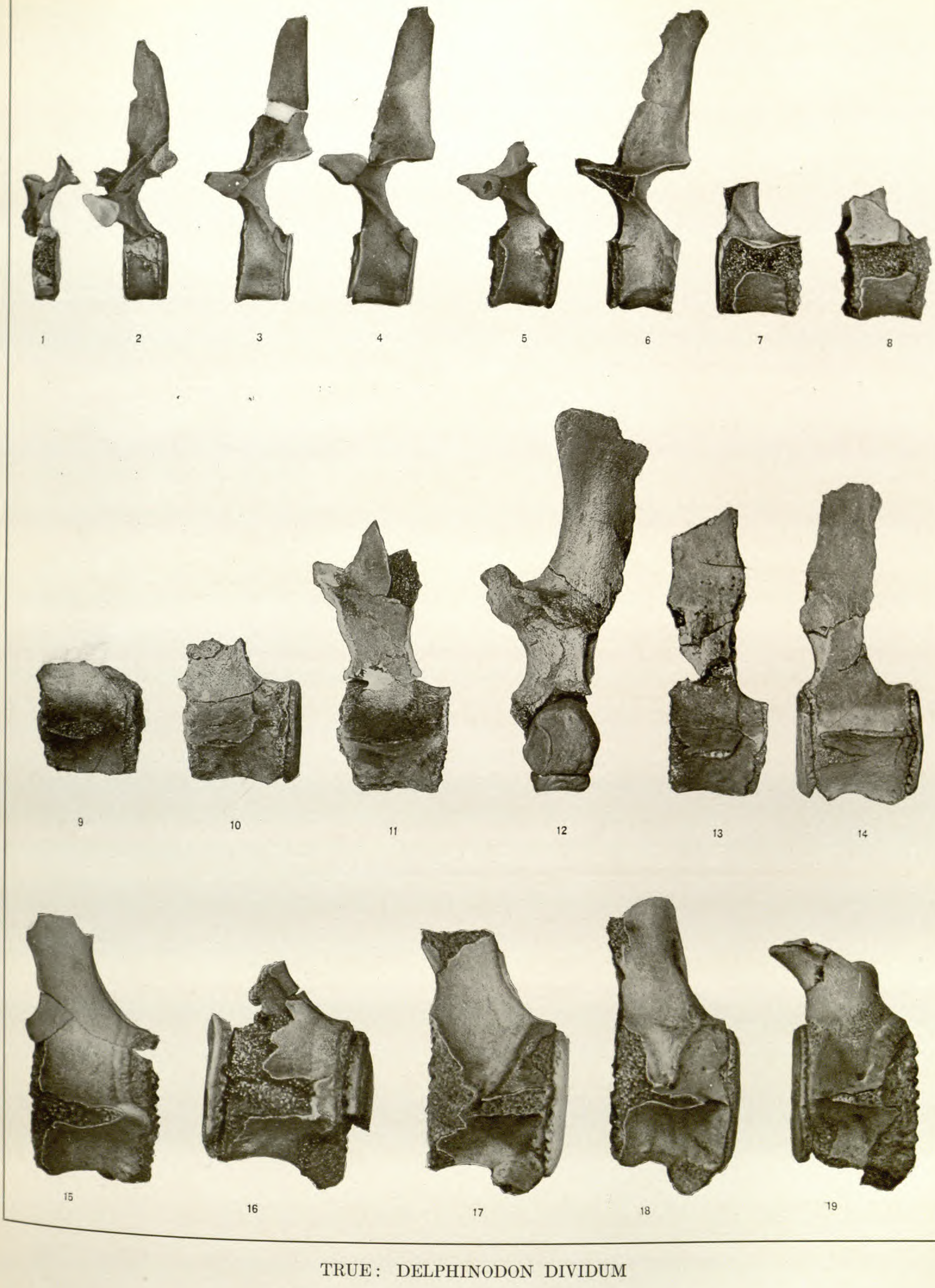
PLATE XX.

FIGS. 1 to 9. Thoracic vertebræ, lateral aspect. Fig. 1, first; fig. 2, third; fig. 3, fourth; fig. 4, fifth; fig. 5, sixth; fig. 6, seventh.

FIGS. 10–14. Lumbar vertebræ, lateral aspect.

FIGS. 15–19. Caudal vertebræ, lateral aspect. Fig. 15, first caudal.

About two-thirds natural size.



TRUE: DELPHINODON DIVIDUM

PLATE XXI.

FIGS. 1– 9. Thoracic vertebræ. (Fig. 5 should stand behind fig. 6 instead of in front of it.)
FIGS. 10–14. Lumbar vertebræ.
FIGS. 15–19. Caudal vertebræ.
Superior aspect. About seven-tenths natural size.

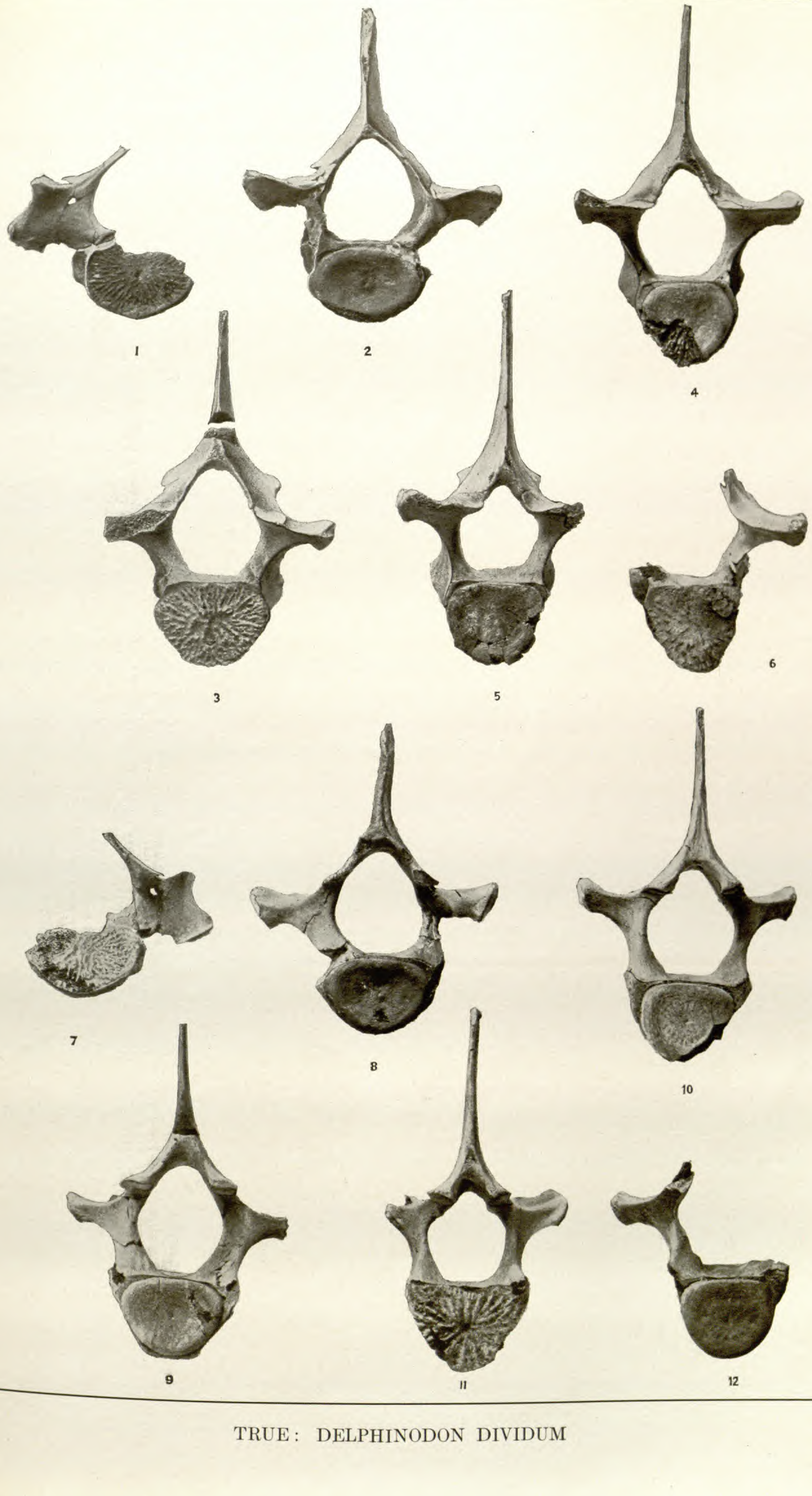
TRUE: DELPHINODON DIVIDUM

PLATE XXII.

FIGS. 1– 6. Thoracic vertebræ, anterior aspect.

FIGS. 7–12. Thoracic vertebræ, posterior aspect. Figs. 1 and 3, first; figs. 2 and 8, third; figs. 3 and 9, fourth; figs. 4 and 10, fifth; figs. 5 and 11, seventh; figs. 6 and 12, sixth.

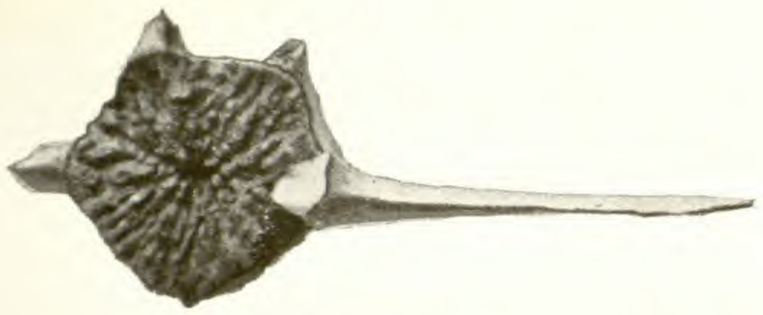
About seven-tenths natural size.



TRUE: DELPHINODON DIVIDUM

PLATE XXIII.

FIGS. 1– 6. Lumbar vertebræ, anterior aspect.
FIGS. 7–11. Caudal vertebræ, anterior aspect.
About seven-tenths natural size.



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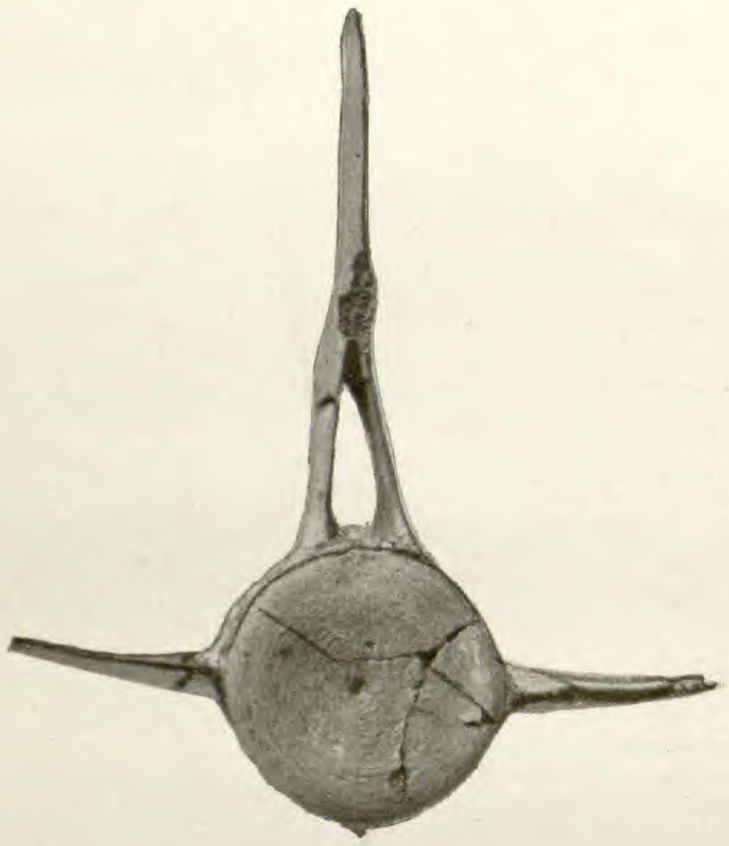

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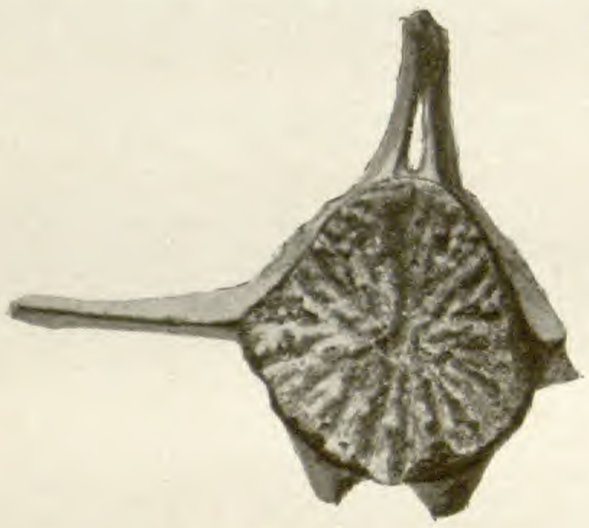

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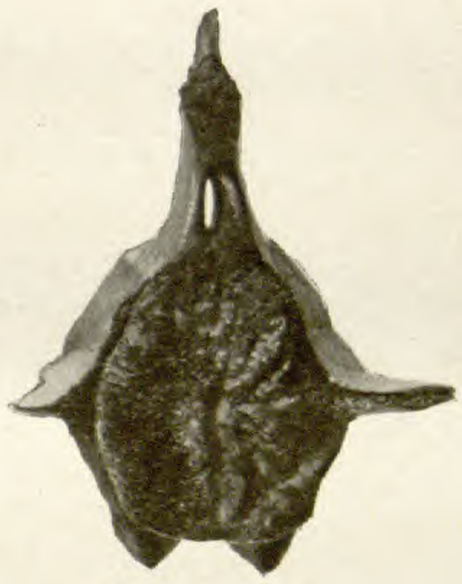

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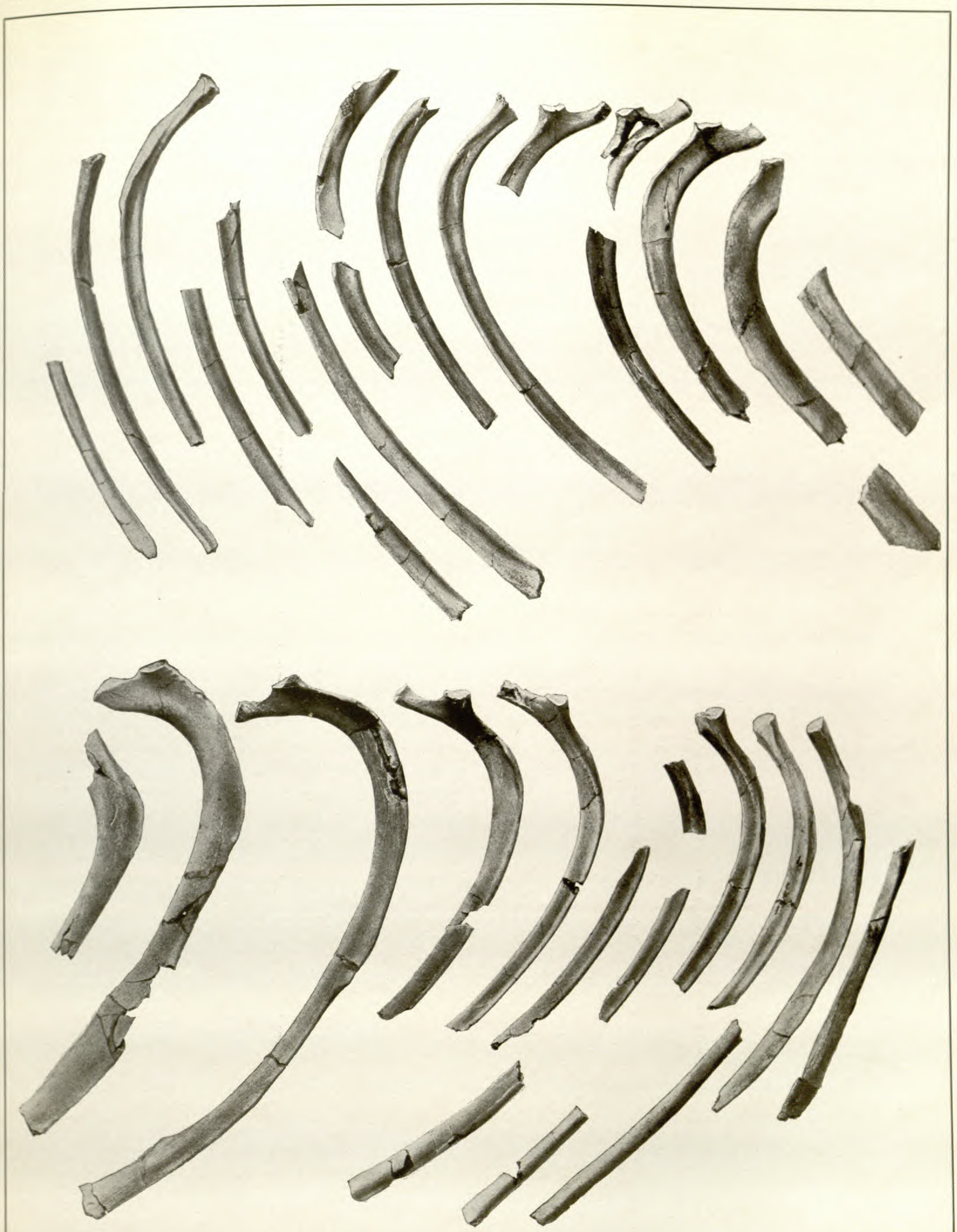
TRUE: DELPHINODON DIVIDUM

PLATE XXIV.

Ribs. About two-thirds natural size.



TRUE: DELPHINODON DIVIDUM

PLATE XXV.

FIG. 1. Right scapula, internal surface.

FIG. 2. Left humerus, external surface.

FIG. 3. Radius.

FIG. 4. Ulna.

FIG. 5. Hyoid bones.

FIG. 6. Left periotic bone, internal aspect.

FIG. 7. Left periotic bone, external aspect.

FIGS. 8–11. Two other periotic bones of the same species, from Chesapeake Beach. More or less water-worn.

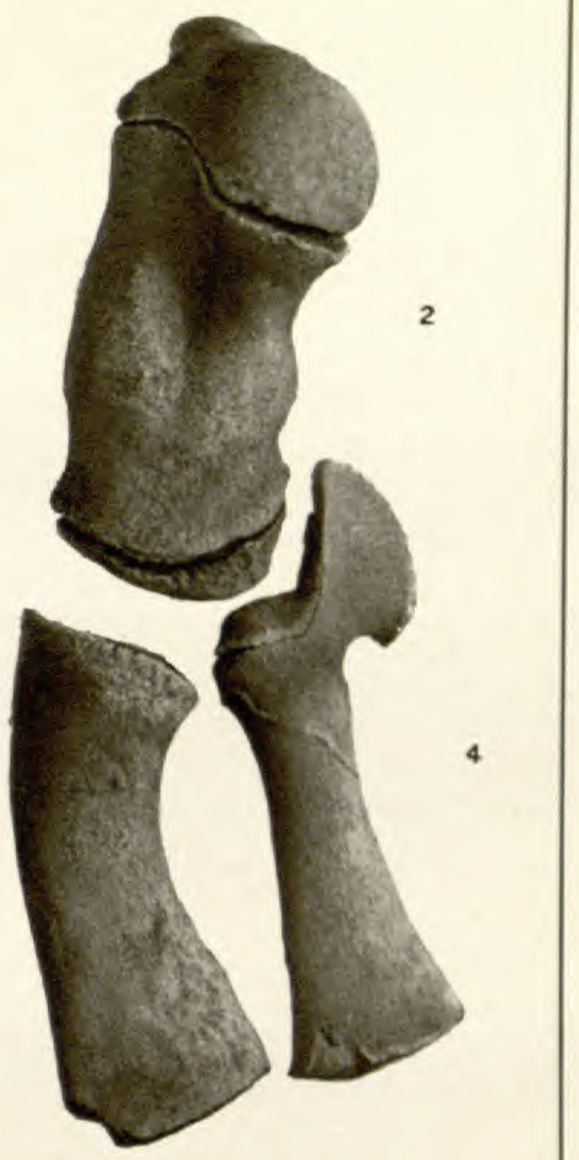
FIG. 12. Right tympanic bone. Inferior aspect.

FIG. 13. Right tympanic bone. Exterior aspect.

FIGS. 14–17. Other fragmentary tympanic bones of the same species, from Chesapeake Beach. Water-worn.

FIGS. 1–4, about seven-tenths natural size; fig. 5, about two-thirds natural size; figs. 6–17, natural size.

1



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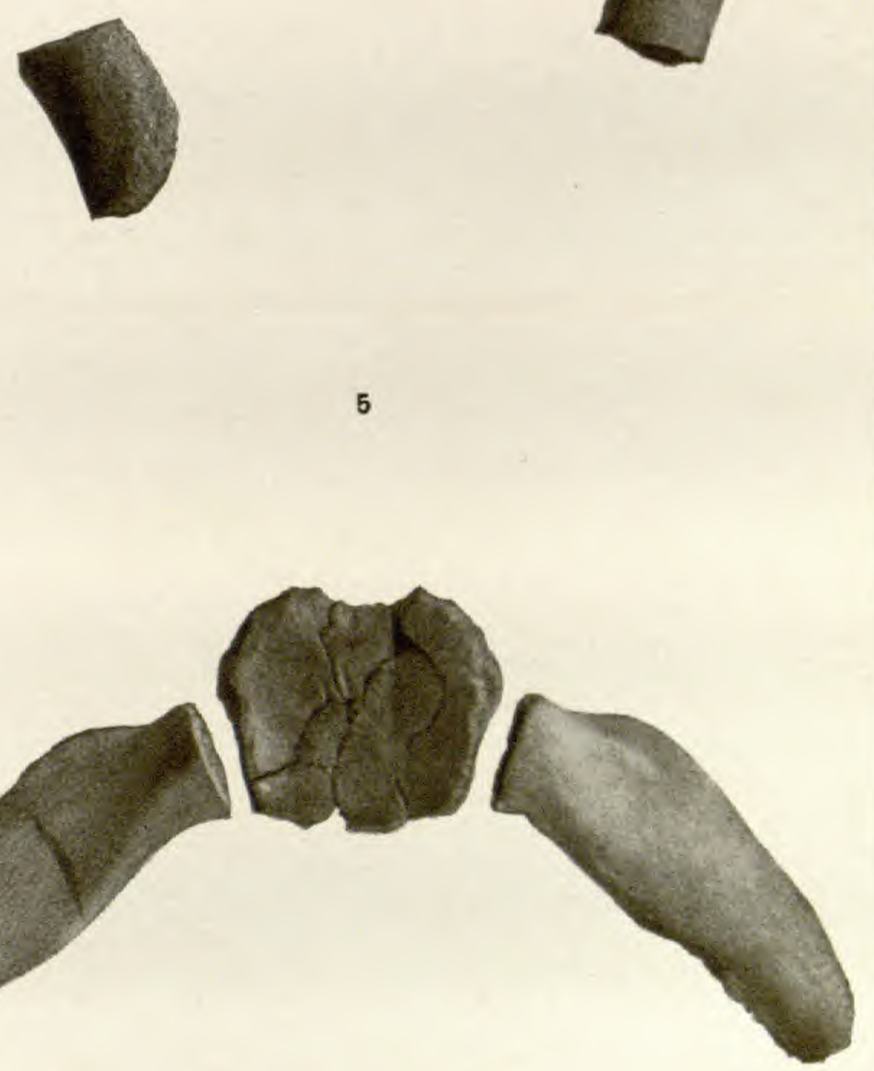
6 8 10

7 9 11

12 14 16

13 15 17



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TRUE: DELPHINODON DIVIDUM

PLATE XXVI.

FIGS. 1–20. Teeth (numbered to agree with the enumeration of detached teeth at the top of the table of measurements on pp. 173, 174).

FIG. 1. Lower left, No. 1.
FIG. 2. Lower left, No .2.
FIG. 3. Lower left, No. 2.
FIG. 4. Lower left, No. 6.
FIG. 5. Lower left, No. 1.
FIG. 6. Lower left, No. 2.
FIG. 7. Lower left, No. 3.
FIG. 8. Lower right, No. 5.
FIG. 9. Lower left, No. 6.
FIG. 10. Lower right, No. 3.
FIG. 11. Lower right, No. 5.
FIG. 12. Lower left, No. 3.
FIG. 13. Lower right, No. 3.
FIG. 14. Upper right, No. 1.
FIG. 15. Upper right, No. 4.
FIG. 16. Upper right, No. 6.
FIG. 17. Upper right, No. 1.
FIG. 18. Upper right, No. 4.
FIG. 19. Upper right, No. 6.
FIG. 20. Upper right, No. 7.

All figures 2½ times natural size.

TRUE: DELPHINODON DIVIDUM

A Synopsis of the Fishes of the Genus Mastacembelus

BY

GEORGE A. BOULENGER, D.Sc., Ph.D., F.R.S.

PHILADELPHIA
1912

A SYNOPSIS OF THE FISHES OF THE GENUS MASTACEMBELUS.

By George A. Boulenger, D.Sc., Ph.D., F.R.S.

The genus *Mastacembelus*, forming with *Rhynchobdella* the very natural family *Mastacembelidæ*, is characterized among Acanthopterygians by an eel-like form, by the absence of ventral fins, by the position of the anterior nostril widely separated from the posterior and opening in a tentacle on each side of a dermal rostral appendage, and especially by the peculiarity of the shoulder-girdle, which is not suspended from the skull, a character which is shared by the true eels.

This is one of the genera our knowledge of which has been enormously increased within the last few years by the exploration of the fresh waters of Africa. When the last account of it was published in Günther's *Catalogue of Fishes*, Vol. III (1861), only eight species were known—seven from the Indian Region, and one from the Euphrates. We are now acquainted with forty-five species, which are distributed as follows: 30 from tropical Africa, 12 from S. E. Asia (Indian or Oriental Region), 2 from S. W. Asia (Euphrates and Oxus), and 1 from China (Yangtse-kiang).

The descriptions of these forty-five species, twenty-seven of which have been named by myself, are at present scattered through a great number of books and periodicals, and some of the older diagnoses fail to furnish the characters requisite for their proper identification. I have therefore thought it would be useful to avail myself of the large collection in the British Museum for drawing up a key to the identification of the species, of which a list, with the necessary synonymy, is appended.

In dealing with the distribution of fresh-water fishes in his *Introduction to the Study of Fishes* (1880), Günther has observed that "as a general rule a genus or family of fresh-water fishes is regularly dispersed and most developed within a certain district, the species and individuals becoming scarcer towards the periphery as the type recedes more from its central home, some outposts being frequently pushed far beyond the outskirts of the area occupied by it." And further on he writes: "*Mastacembelus* and *Ophiocephalus*, genera characteristic of the Indian region, emerge severally by a single species in West and Central Africa"; and, comparing the fishes of the Indian and African regions, he adds: "A few species only have found their way into Africa." At present, the state of things known thirty years ago is reversed, as twice as many species have been described from Africa as from Asia. And yet, I think Günther is right in assigning an Indian origin to the group, for in India and Burma only do we find forms (species 1 to 3) with the caudal fin quite free from the dorsal and anal, a character which, as in the eels, is surely to be regarded as primitive; on the other hand, all

African species are characterized, in common with a few Asiatic species, by complete fusion of the vertical fins, forms intermediate between the two extremes occurring in the Euphrates and in Burma and the Malay Archipelago.

Synopsis of the Species.

I. Snout entirely scaly; 3 anal spines, close together, second largest; vent nearer base of caudal than end of snout; a preorbital spine.

A. Caudal fin free from dorsal at anal; 3 to 5 preopercular spines; length of head 5 to 6 times in total length; mouth not extending to below nostril.

D. XXIV–XXVI 30–42; A. III 31–46.....1. *M. pancalus*, Ham. Buch.
D. XXVIII–XXIX 50–52; A. III 51–56.....2. *M. zebrinus* Blyth.
D. XXXIII–XXXV 74–94; A. III 75–95.....3. *M. dayi* Blgr.

B. Caudal fin embraced by dorsal and anal; length of head 7 to 8 times in total length.

D. XXVII–XXX 58–74; A. III 62–75; 2 preopercular spines; mouth not extending to below nostril. 4. *M. guentheri* Day.
D. XXVI–XXX 60–70; A. III 59–69; no preopercular spines; mouth extending to below nostril. 5. *M. maculatus* C. & V.

II. Snout naked, or scaly only on the sides.

A. Anal spines 3, the third large and widely separated from the others; vent much nearer base of caudal than end of snout; a preorbital but no preopercular spine; caudal fin confluent with dorsal and anal; mouth extending to below anterior border of eye.

D. XXXIII–XXXV 60–72; A. III 65–70.....6. *M. sinensis* Blkr.

B. Anal spines, if more than one, close together.

1. Caudal fin embraced by dorsal and anal, but separated from either or both by a notch; vent nearer base of caudal than end of snout; a preorbital spine.

a. No preopercular spines.

D. XXXII–XXXV 80–90; A. III 80–90; mouth extending to below anterior border of eye; head 6½–7½ times in total length.....7. *M. haleppensis* Bl. Schn.
D. XXXII–XXXIV 75–85; A. III 75–85; mouth extending to below nostril; head 6½ times in total length.....8. *M. unicolor* C. & V.
D. XXXI–XXXIII 62–66; A. III 60–65; mouth not extending to below nostril; head 5 to 5⅓ times in total length.....9. *M. caudiocellatus* Blgr.

b. Preopercular spines; cleft of mouth not extending to below nostril; head 6½ to 7 times in total length.

D. XXIX–XXXIII 48–55; A. III 46–55; 4 or 5 preopercular spines.....10. *M. oatesii* Blgr.
D. XXXV–XXXVI 75–85; A. III 70–80; 3 preopercular spines.....11. *M. alboguttatus* Blgr.

2. Caudal fin completely united with caudal.

a. Vent considerably nearer caudal fin than end of snout.

α. 3 anal spines; preopercular spines present.

* A preorbital spine; mouth extending to below nostril, or between nostril and eye.

D. XXXIV–XXXIX 80–90; A. III 80–90.....12. *M. armatus* Lacep.
D. XXXII–XXXIV 65–75; A. III 65–75.....13. *M. argus* Gthr.

** No preorbital spine.

D. XXXII–XXXVII 70–80; A. III 70–80; mouth extending to below nostril 14. *M. erythrotænia* Blkr.
D. XXXVI 80; A. III 85; mouth extending to below anterior third of eye....15. *M. caudatus* McClell.
D. XXXI 95; A. III 70; mouth not to below anterior border of eye.....16. *M. trispinosus* Stdr.

β. 2 anal spines.

* 29 to 32 dorsal spines.

† Preorbital and preopercular spines present.

D. XXIX–XXX 110; A. II 110; mouth extending to below anterior border of eye. 17. *M. ubangensis* Blgr.
D XXXI 70; A. II 70; mouth not extending to below nostril.....18. *M. ellipsifer* Blgr.

†† No preorbital spine; preopercular spines present.

D. XXX–XXXII 85; A. II 70; mouth extending to below posterior border of eye; depth of body nearly 20 times in total length.....19. *M. marmoratus* Perugia.
D. XXIX–XXXII 70–80; A. II 70–80; mouth extending to below eye; depth of body 13 to 14 times in total length.....20. *M. brevicauda* Blgr.
D. XXXI–XXXII 90; A. II 90–95; mouth extending to below nostril; depth of body 11 to 12 times in total length.....21. *M. reticulatus* Blgr.

††† No preorbital or preopercular spine.

D. XXXI 51; A. II 53.....22. *M. brachyrhinus* Blgr.

** 33 to 39 dorsal spines; no preorbital spine.

D. XXXIII–XXXV 85; A. II 85; no preopercular spine.....23. *M. tæniatus* Blgr.

D. XXXVI–XXXIX 50–60; A. II 50–60; one preopercular spine.....24. *M. tanganicae* Gthr.

b. Vent equally or nearly equally distant from end of snout and from caudal fin.

α. 25 to 35 dorsal spines; no preorbital or preopercular spines; 2 anal spines.

* Head (to gill-opening) $\frac{4}{5}$ to $1\frac{1}{2}$ times as long as its distance from first dorsal spine.

D. XXVII 80–90; A. II 68–80; no lateral line.....25. *M. niger* Sauv.

D. XXV–XXVIII 70–80; A. II 80–90; lateral line formed of a few tubules widely separated from one another.....26. *M. flavomarginatus* Blgr.

D. XXX–XXXIII 80–90; A. II 80–90; lateral line formed of a few tubules widely separated from one another.....27. *M. batesii* Blgr.

** Head 2 to 3 times as long as its distance from first dorsal spine.

D. XXV–XXVII 70–80; A. II 70–80; mouth extending to below center of eye; 30–35 scales between origin of soft dorsal and lateral line.....28. *M. moorii* Blgr.

D. XXVI–XXIX 65–70; A. II 68–75; mouth extending to below anterior border of eye; 18–22 scales between origin of soft dorsal and lateral line.....29. *M. shiranus* Gthr.

D. XXVIII–XXIX 95–100; A. II 85–90; mouth extending to below anterior border or anterior third of eye; 23–25 scales between origin of soft dorsal and lateral line...30. *M. nigromarginatus* Blgr.

D. XXXII–XXXV 100; A. II 100; mouth extending to below nostril; about 20 scales between origin of soft dorsal and lateral line.....31. *M. victoriæ* Blgr.

β. 25 to 34 dorsal spines; preopercular spines present.

* 3 anal spines; a strong preorbital spine.

D. XXV–XXVIII 85–90; A. III 85–92.....32. *M. congicus* Blgr.

D. XXIX 85; A. III 85.....33. *M. signatus* Blgr.

** 2 anal spines.

† No preorbital spine; length of head 3 to $4\frac{1}{3}$ times in its distance from vent.

D. XXXIV 128; A. II 120.....34. *M. ansorgii* Blgr.

D. XXIX–XXXII 80–85; A. II 80–85.....35. *M. goro* Blgr.

†† A small preorbital spine; length of head $2\frac{2}{3}$ to $3\frac{1}{3}$ times in its distance from vent.

D. XXVIII–XXXII 110–130; A. II 110–130; depth of body 14 to 17 times in total length.
35. *M. loennbergii* Blgr.

D. XXVI–XXX 80; A. II 80; depth of body 12 to 13 times in total length....36. *M. liberiensis* Blgr.

††† A strong preorbital spine; length of head $2\frac{1}{4}$ to $2\frac{3}{4}$ times in its distance from vent.

D. XXVIII–XXIX 95–105; A. II 115–125.....37. *M. cunningtoni* Blgr.

D. XXVI–XXVII 85–90; A. II 80–90.....38. *M. sclateri* Blgr.

γ. 23 or 24 dorsal spines; 2 anal spines; preopercular spines present.

D. XXIV 100; A. II 100; no preorbital spine; length of head $3\frac{1}{2}$ times in its distance from vent.
39. *M. cryptacanthus* Gthr.

D. XXIII–XXIV 75; A. II 75–80; a preorbital spine; length of head twice in its distance from vent.
40. *M. marchii* Sauv.

δ. Less than 20 dorsal spines; no preorbital or preopercular spines.

D. XVIII 85; A. II 90; length of head $8\frac{2}{3}$ times in total length.....41. *M. frenatus* Blgr.

D. VII 105; A. III 70; length of head $5\frac{1}{4}$ times in total length.....42. *M. paucispinis* Blgr.

c. Vent considerably nearer end of snout than caudal.

D. XXV–XXVIII 125–150; A. II 125–150; no preorbital spine; 2 preopercular spines.
43. *M. longicauda* Blgr.

D. XXXI 150; A. II 150; a preorbital and 4 preopercular spines.....44. *M. greshoffi* Blgr.

D. XXX–XXXIII 100–120; A. I 115–130; no preorbital or preorbicular spine,
45. *M. ophidium* Gthr.

1. **Mastacembelus pancalus.**

Macrognathus pancalus Ham. Buchan., Fish. Ganges, p. 30, pl. XXII, fig. 7 (1822).

Mastacembelus pancalus Cuv. & Val., Hist. Poiss., VIII, p. 455 (1831); Günth., Cat. Fish., III, p. 541 (1861); Day, Fish. Ind., p. 340, pl. LXXII, fig. 4 (1876).

Mastacembelus punctatus Cuv. & Val., t. c., p. 463.

Ganges and Lower Kistna.

2. **Mastacembelus zebrinus.**

Blyth, Journ. Asiat. Soc. Beng., XXVII, 1859, p. 281; Günth., Cat. Fish., III, p. 541 (1861); Day, Fish. Ind., p. 339, pl. LXXII, fig. 3 (1876); Vincig., Ann. Mus. Genova (2), IX, 1890, p. 178.

Irawaddy.

3. **Mastacembelus dayi.**
Mastacembelus unicolor (non Cuv. & Val.) Day, Fish. Ind., p. 339, pl. LXXII, fig. 2 (1876); Vincig., Ann. Mus. Genova (2), IX, 1890, p. 179.

Irawaddy.

4. **Mastacembelus guentheri.**
? *Mastacembelus malabaricus* Jerdon, Madras Journ. Lit. & Sc., XV, 1848, p. 147.
Mastacembelus guentheri Day, Proc. Zool. Soc., 1865, p. 37, Fish. Malab., p. 154, pl. XI, and Fish. Ind., p. 341, pl. LXXIII, fig. 3 (1876).

Malabar coast.

5. **Mastacembelus maculatus.**
Cuv. & Val., Hist. Poiss., VIII, p. 461 (1831), and Règne Anim. Illustr., Poiss., pl. LV, fig. 1 (1836); Bleek., Nat. Tijdschr. Nederl. Ind., III, 1852, p. 93; Günth., Cat. Fish., VIII, p. 543 (1861).
Rhynchobdella maculata Bleek., Versl. Ak. Amsterd. (2), IV, 1870, p. 250.
Pararhynchobdella maculata Bleek., op. cit., VIII, 1874, p. 368.
Mastacembelus guentheri (non Day) Vaill., N. Arch. Mus. (3), V, 1893, p. 106.
Mastacembelus vaillanti Fowler, Proc. Acad. Philad., 1905, p. 491, fig. 8.

Sumatra, Biliton, Borneo, Java.

6. **Mastacembelus sinensis.**
Rhynchobdella sinensis Bleek., Versl. Ak. Amsterd., IV, 1870, p. 249, pl. [VI?], fig. 2.
Mastacembelus sinensis Günth., Ann. & Mag. N. H. (4), XII, 1873, p. 243.

Yang-tse-kiang.

7. **Mastacembelus haleppensis.**
Simak-el-inglese A. Russell, Nat. Hist. Aleppo, p. 75, pl. XII, fig. 2 (1756).
Mastacembelus sp., Gronow, Zoophyl., p. 132 (1781).
Ophidium simak Walb., Artedi Ichthyol., III., p. 159 (1792).
Rhynchobdella haleppensis Bloch, Schneid. Syst. Ichth., p. 480 (1801).
Ophidium mastacembelus Shaw, Zool., IV, p. 71 (1803).
Mastacembelus haleppensis Cuv. & Val., Hist. Poiss., VIII, p. 454 (1831); Heckel, in Russegger's Reis. Griechenl., etc., II, pl. XIX, fig. 3 (1843).
Mastacembelus syriacus Gronow, Cat. Fish., p. 172 (1854).
Mastacembelus aleppensis part. Günth., Cat. Fish., III, p. 541 (1861).

Tigris and Euphrates.

8. **Mastacembelus unicolor.**
Cuv. & Val., Hist. Poiss., VIII, p. 453 (1831); Bleek., Verh. Batav. Gen., XXIII, 1850, Notac., p. 5; Günth., Cat. Fish., III, p. 542 (1861); Fowler, Proc. Acad. Philad., 1905, p. 489.

Banka, Sumatra, Borneo, Java.

9. **Mastacembelus caudiocellatus.**
Bouleng., Ann. & Mag. N. H. (6), XII, 1893, p. 199.

Irawaddy.

10. **Mastacembelus oatesii.**
Bouleng., Ann. & Mag. N. H. (6), XII, 1893, p. 199.

Irawaddy.

11. **Mastacembelus alboguttatus.**
Bouleng., Ann. &. Mag. N. H. (6), XII, 1893, p. 200.

Sittang R., Burma.

12. **Mastacembelus armatus.**
Macrognathus armatus Lacep., Hist. Poiss., II, p. 286 (1800); Ham. Buchan., Fish. Ganges, p. 28, pl. XXXVII, fig. 6 (1822).
Rhynchobdella polyacantha Bloch, Schn., Syst. Ichthyol., p. 479 (1801).
Mastacembelus armatus Cuv. & Val., Hist. Poiss., VIII, p. 456, pl. CCXL (1831); Günth., Cat. Fish., III, p. 542 (1861); Day, Fish. Ind., p. 340, pl. LXXIII, fig. 2 (1876); Vincig., Ann. Mus. Genov. (2), IX, 1890, p. 180.
Mastacembelus ponticerianus Cuv. & Val., t. c., p. 460.
Mastacembelus marmoratus Cuv. & Val., t. c., p. 461, and in Jacquemont, Voy. Inde, Poiss., pl. XIV, fig. 2 (1844).
Macrognathus undulatus MacClell., Calcutta Journ. N. H., IV, 1844, pp. 393, 398, pl. XXII, fig. 1.

Macrognathus hamiltonii MacClell., t. c., p. 393.
Mastacembelus venosus Val., in Jacquem., op. cit., pl. XIV, fig. 1.
India, Ceylon, and S. China to the Malay Peninsula and Sumatra.

13. **Mastacembelus argus.**
Günth., Cat. Fish., III, p. 542 (1861); Martens, Preuss. Exped. O.-As., Zool., I, p. 210, pl. X, fig. 4 (1865).
Siam.

14. **Mastacembelus erythrotænia.**
Bleek., Verh. Batav. Gen., XXIII., 1850, Notac., p. 6; Günth., Cat. Fish., III, p. 542 (1861).
Malay Peninsula, Sumatra, Borneo.

15. **Mastacembelus caudatus.**
Macrognathus caudatus McClell. & Griffith, Calcutta Journ. N. H., II, 1842, pp. 573 and 586.
Mastacembelus aleppensis part. (spec. *d*) Günth., Cat. Fish., III, p. 541 (1861).
Afghanistan (Oxus?).

16. **Mastacembelus trispinosus.**
Steind., Anz. Ak. Wien., 1911, p. 529.
Ituri R., Congo.

17. **Mastacembelus ubangensis.**
Bouleng., Ann. & Mag. N. H. (8), VIII, 1911, p. 638.
Ubanghi R., Congo.

18. **Mastacembelus ellipsifer.**
Bouleng., Ann. Mus. Congo, Zool., I, p. 126, pl. XLII, fig. 4 (1899), and Poiss. Bass. Congo, p. 496, pl. XXIV, fig. 2 (1901).
Lake Tanganyika.

19. **Mastacembelus marmoratus.**
Perugia, Ann. Mus. Genova (2), X, 1892, p. 968; Bouleng., Poiss. Bass. Congo, p. 495 (1901).
Lower Congo.

20. **Mastacembelus brevicauda.**
Bouleng., Ann. & Mag. N. H. (8), VIII, 1911, p. 638.
South Cameroon.

21. **Mastacembelus reticulatus.**
Bouleng., Ann. & Mag. N. H. (8), VIII, 1911, p. 638.
? *Mastacembelus cryptacanthus* (non Günth.) Steind., Denkschr. Ak. Wien., XLI, 1879, p. 16.
Sierra Leone.

22. **Mastacembelus brachyrhinus.**
Bouleng., Ann. Mus. Congo, Zool., I, p. 55, pl. XXVIII, fig. 4 (1899), and Poiss. Bass. Congo, p. 497 (1901).
Lower Congo.

23. **Mastacembelus tæniatus.**
Bouleng., Ann. & Mag. N. H. (7), VII, 1901, p. 6, Poiss. Bass. Congo, p. 498 (1901), and Tr. Zool. Soc., XVI, 1901, p. 160, pl. XX, fig. 4, and XVII, 1906, p. 576.
Lake Tanganyika.

24. **Mastacembelus tanganicæ.**
Günth., Proc. Zool. Soc., 1893, p. 629, and Ann. & Mag. N. H. (6), XVII, 1896, p. 397; Bouleng., Poiss. Bass. Congo, p. 496 (1901).
Lake Tanganyika.

25. **Mastacembelus niger.**
Sauv., Bull. Soc. Philom. (7), III, 1878, p. 95, and N. Arch. Mus. (2), III, 1880, p. 37.
Ogowe.

26. **Mastacembelus flavomarginatus.**
Bouleng., Tr. Zool. Soc., XV, 1898, p. 23.
Mastacembelus cryptacanthus part. Günth., Ann. & Mag. N. H. (3), XX, 1867, p. 110.
South Cameron to Portuguese Congo.

27. **Mastacembelus batesii.**
Bouleng., Ann. & Mag. N. H. (8), VIII, 1911, p. 638.
South Cameroon (Congo Basin).

28. **Mastacembelus moorii.**
Bouleng., Tr. Zool. Soc., XV, 1898, p. 22, pl. VII, fig. 1; Poiss. Bass. Congo, p. 493 (1901), and Tr. Zool. Soc., XVII, 1906, p. 575.
Lake Tanganyika.

29. **Mastacembelus shiranus.**
Günth., Ann. & Mag. N. H. (6), XVII, 1896, p. 397.
Lake Nyassa and Upper Shiré R.

30. **Mastacembelus nigromarginatus.**
Bouleng., Tr. Zool. Soc., XV, 1898, p. 23.
Ashantee.

31. **Mastacembelus victoriæ.**
Bouleng., Ann. & Mag. N. H. (7), XII, 1903, p. 218, and Fish. Nile, p. 541, fig. (1907).
Lake Victoria and Victoria Nile.

32. **Mastacembelus congicus.**
Bouleng., Ann. & Mag. N. H. (6), XVII, 1896, p. 311, and Poiss. Bass. Congo, p. 494 (1901).
Congo, Gaboon.

33. **Mastacembelus signatus.**
Bouleng., Ann. & Mag. N. H. (7), XVI, 1905, p. 647.
Lake Bangwelu, Congo.

34. **Mastacembelus ansorgii.**
Bouleng., Ann. & Mag. N. H. (7), XV, 1905, p. 459.
Quanza R., Angola.

35. **Mastacembelus loennbergii.**
Mastacembelus cryptacanthus (non Günth.) Lönnb., Öfvers. Vet.-Ak. Forh. Stockholm, 1895, no. 3, p. 181.
Mastacembelus lœnnbergii Bouleng., Tr. Zool. Soc., XV, 1898, p. 23, and Proc. Zool. Soc., 1902, II, p. 329, pl. XXIX, fig. 3.
Lower Niger to Cameroon.

36. **Mastacembelus liberiensis.**
Mastacembelus marchei (non Sauv.) Steind., Notes Leyd. Mus., XVI, 1894, p. 31.
Mastacembelus liberiensis Bouleng., Tr. Zool. Soc., XV, 1898, p. 23.
Liberia.

37. **Mastacembelus cunningtoni.**
Bouleng., Tr. Zool. Soc., XVII, 1906, p. 575, pl. XLI, fig. 3; Steind., Anz. Ak. Wien., 1909, p. 388.
Lake Tanganyika.

38. **Mastacembelus sclateri.**
Bouleng., Proc. Zool. Soc., 1903, I, p. 28, pl. V, fig. 2.
Cameroon.

39. **Mastacembelus cryptacanthus.**
Günth., Proc. Zool. Soc., 1867, p. 102; Bouleng., Tr. Zool. Soc., XV, 1898, p. 23.
Cameroon.

40. **Mastacembelus marchii.**
Sauv., Bull. Soc. Philom. (7), III, 1878, p. 94, and N. Arch. Mus. (2), III, 1880, p. 36, pl. I, fig. 1; Bouleng., Poiss. Bass. Congo, p. 495 (1901).

Ogowe.

41. **Mastacembelus frenatus.**
Bouleng., Ann. & Mag. N. H. (7), VII, 1901, p. 5, Poiss. Bass. Congo, p. 493 (1901), and Tr. Zool. Soc., XVI, 1901, p. 159, pl. XX, fig. 3, and XVII, 1906, p. 576.

Lake Tanganyika.

42. **Mastacembelus paucispinis.**
Bouleng., Ann. Mus. Congo, Zool., I, p. 55, pl. XXVIII, fig. 3 (1899), and Poiss. Bass. Congo, p. 492, pl. XXIV, fig. 1 (1901).

Lower Congo.

43. **Mastacembelus longicauda.**
Bouleng., Ann. & Mag. N. H. (7), XX, 1907, p. 487.

Cameroon and Calabar.

44. **Mastacembelus greshoffi.**
Bouleng., Ann. & Mag. N. H. (7), VII, 1901, p. 81, and Poiss. Bass. Congo, p. 498 (1901).

Stanley Pool, Congo.

45. **Mastacembelus ophidium.**
Günth., Proc. Zool. Soc., 1893, p. 630; Bouleng., Poiss. Bass. Congo, p. 499 (1901), and Tr. Zool. Soc., XVII, 1906, p. 576.

Lake Tanganyika.

The Faunal Divisions of Eastern North America in Relation to Vegetation

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1912

THE FAUNAL DIVISIONS OF EASTERN NORTH AMERICA IN RELATION TO VEGETATION.

By Spencer Trotter, M.D.

Two quite distinct ideas are associated in the word *fauna*—the one zoological, the other geographical. The term blends these two conceptions most happily, for it connotes the natural surroundings that are so inseparably interwoven in our thought of the living animal world. Its place is in the vocabulary of science, yet the word savors of a remote past when woods and fields were haunted by strange animal divinities and men were closer to the life about them, and knew it more sympathetically and more intimately, if less accurately, than in later times. In its modern scientific usage, *fauna* signifies the varied assemblage of animal species inhabiting a particular region. It may be, and frequently is, broadly applied to the animal life of an extensive area of land or sea, and likewise to some particular class of animals, as birds or fishes, in relation to their distribution. In a more restricted and technical sense the word denotes the collective animal life of an area of more or less uniform and distinctive environmental conditions. In such a sense it is used by zoogeographers to designate the subdivisions of the large regional zones of distribution that characterize a continent.

The current classification of North American faunal areas is that of Dr. C. Hart Merriam[1] who recognizes the continent as primarily divided into two dominant zones which extend across its entire breadth—a northern or Boreal Zone, of environmental conditions similar to the northern zone of Eurasia, and a southern Austral or Sonoran Zone. Between these two Merriam recognizes a more or less narrow area of overlap which he calls the Transition Zone. This zonal arrangement of life is based on temperature. The Austral or Sonoran is further divided into an upper and lower zone based on observed differences of temperature and differences in faunal distribution. The Sonoran is further divided east and west into a humid and an arid province. Within these zones are recognized certain regional subdivisions characterized by an assemblage of animal species of more restricted distribution. These subdivisions have been termed *faunas*. Their recognition long antedates Merriam's zonal scheme. The late Prof. Edward D. Cope in an essay on geographical distribution accompanying his list of North American Batrachia and Reptilia[2] uses the term "district" to define these faunal subdivisions, while he calls the larger, primary divisions "regions." Cope did not regard the distribution of North American life as any way zonal in character. Merriam, on the other hand, lays particular

[1] See reference in North American Fauna, No. 3 (1890); also The Geographic Distribution of Life in North America, by C. Hart Merriam, M.D., from the *Smithsonian Report* for 1891, p. 365.

[2] *Bulletin of the U. S. National Museum*, Washington, 1875.

stress on the zonal feature and correlates the older divisions of regions and faunas with these zones. I have taken these two writers as illustrating the older and the more recent views of North American zoogeographers, not mentioning the many other able investigators who have done so much to enrich this branch of the science.

Merriam presents an array of distributional phenomena which he correlates with the results of extensive temperature observations to show this zonal arrangement, and he formulates from the whole mass of evidence a series of laws of "temperature control."[1]

Unquestionably temperature does exert an influence in the distribution of living beings, especially in the case of plants, but it is not, I think, as Dr. Merriam would have us believe, the supreme cause of the present phases of dispersal. In the first place the attempt to arrange the animal life of a land in a series of zones based on temperature is, to say the least, misleading and unnatural. There are, as we well know, marked contrasts between the animal life of the tropics and that of the temperate regions, and the species in each are more or less adjusted to the prevailing conditions of heat and moisture. The degree of temperature, however, is not the *cause* of this contrast. Dr. Merriam claims that each species is bound to its region through some special peculiarity in its reproductive metabolism in relation to temperature, or what he calls its "physiological constant." It is hard to believe that the African antelopes are so widely differentiated from other bovine species that inhabit more northerly regions by this functional relation to temperature, or that the two species of reindeer, the one of the Barren Grounds, the other of the woodland farther to the south, should be limited to their respective ranges solely through temperature conditions. Or again, that one variety of tiger is limited only by this temperature control to the hot, low-lying jungles of the southern peninsular lands of Asia, while a nearly related one inhabits the cold and snowy region of Manchuria. Case after case might be cited throughout the different groups of animals of closely related species thus separated in areas of contrasted temperatures, but the "physiological" or "heat constant" theory will hardly explain the facts. Again, how are we to account for the differences in the types of animals found in an east and west direction through this temperature relation? The aggregate of daily temperatures taken throughout the period of reproductive activity (*i. e.*, the spring and summer of the north) is regarded by Dr. Merriam as the essential limiting factor in the distribution of species. Thus an aggregate of less than ten thousand degrees Fahrenheit is characteristic of the Boreal Zone, and all the forms of life within its borders are adjusted to temperatures below this point. Undoubtedly they are, to a certain extent, but at the same time this aggregate of temperature does not explain the past history of the fauna within this zone, and it is altogether too vague and too sweeping a conception to be taken as

[1] Laws of Temperature Control of the Geographic Distribution of Terrestrial Animals and Plants, *National Geographic Magazine*, vol. VI, 1894, pp. 229–238.

representing the real conditions. These large aggregates of temperature savor too much of a drag-net. Furthermore, this "temperature control" theory ignores several very real and vital factors in the distribution of animals, such as the character of the vegetation and related soil conditions, the influence of local habitat areas, throughout a region, and the fundamental fact that the species which embody a fauna are mobile elements, not hard and fast fixtures in their environment, and that their present phase of distribution is a part of their past history.

In a paper read before the Delaware Valley Ornithological Club in March, 1909,[1] I stated my belief that "species and faunas alike are but passing phases in the vast cosmic processes of a continent's history," and that there is evidence, at least among birds, "that our so-called 'faunas'—Carolinian, Alleghanian, and Canadian—in reality represent a somewhat temporary state of groups of species in relation to breeding areas, and the more or less arbitrary boundaries of these faunas represent our knowledge only of the present conditions of distribution in a gradual and general northward movement of considerable antiquity." The distribution of animal species is unquestionably closely associated with the distribution of vegetation, and this in turn is influenced by the climatic factors of temperature and moisture, and by soil conditions. A certain type of vegetation may be said to form a *unit of distribution* for certain species of animals, and these species will spread throughout the area covered by this type of plant growth. During their long history they have become more or less adapted to the vegetational and to the climatic conditions of the area in question and have spread with the spread of the particular kind of vegetation that characterizes it. An assemblage of animal species related in this way to certain broad vegetation areas constitutes a *fauna*. Within the limits of such an area certain diversities occur as the result of varied topographical, climatic, and soil conditions which produce certain more or less local characteristic forms of vegetation. These may be regarded as *habitats*, and the assemblage of animal species formed there as constituting a *habitat group* or *type*. Each fauna and its several types must be looked upon as representing only an existing phase of distribution, the reason for its present existence as a fauna or type being the result of a long series of past events connected with the geological history of the land during later Tertiary and Quaternary times. The influence of the last glacial period, and the widespread migrations of animals introduced various species and genera from outlying areas, as well as affecting the indigenous forms. The components of any fauna or type may be regarded as its *elements*, and the chief problem connected with these is as to their origin, and their historical relation to the particular fauna in which they occur.[2]

Schimper has pointed out that the differentiation of the earth's vegetation

[1] Trotter, The Geological and Geographical Relations of the Land-Bird Fauna of Northeastern America, *The Auk*, vol. XXVI, July, 1909, pp. 221–233.

[2] For an interesting discussion of the subject see a paper by Charles C. Adams on The Postglacial Dispersal of the North American Biota, *Biological Bulletin*, vol. IX, No. 1, June, 1905, pp. 53–71.

is controlled by three factors—*heat*, *atmospheric precipitation* (*including winds*), and *soil*, and of these "climatic humidity" or precipitation is the most potent influence in producing the broad types of vegetation. He recognizes three such types or "formations": *Woodland*, *Grassland*, and *Desert*, the development and spread of each being related mainly to the abundance of the ground-water in the superficial or the deeper levels of the soil. A good woodland climate, according to Schimper, has "a warm vegetative season, a continuously moist sub-soil, damp and calm air, especially in winter." Grassland depends on "frequent, even if weak, atmospheric precipitation during the vegetative season, so that the superficial soil is kept in a moist condition, and further a moderate degree of heat during the same period." Strong deviations from these two climatic types produce a desert.[1]

I have not attempted in this paper to do more than indicate the general relations existing between faunas and certain broad areas of vegetation and I have confined my observations mainly to the eastern portion of the North American continent. The western half of the continent is a region of exceedingly complex topography as compared with the eastern section. Its mountain ranges, and the belt of arid country to the east, have formed a barrier to the spread of numerous eastern species of animals, although on the other hand, certain species quite characteristic of the east have undoubtedly come originally from this western plateau region. I do not believe that we can regard an Austral Zone as extending entirely across the continent from ocean to ocean. The few typically eastern forms that have spread west are mainly of northerly distribution and related to the coniferous forest which reaches far into the northwest, while the species which are of undoubted plateau origin, when they have penetrated eastward, have not ranged north beyond the deciduous forest to any great extent.

The following outline is a synopsis of the faunal divisions of North America based on the distribution of vegetation. Although this discussion is confined to the east, as stated above, I have included the western aspect of the fauna, in a wholly provisional and inadequate way, merely to complete the general scheme.

Synopsis of the Faunal Divisions of North America.

I. THE SUB-ARCTIC FAUNA.

(*a*) The Barren Ground Type.
(*b*) The Tree-limit Type.

II. THE ATLANTIC FOREST FAUNA.

(*a*) The Coniferous Forest Type.
(*b*) The Deciduous Forest Type.

III. THE COASTAL PLAIN FAUNA.

(*a*) The Alluvial Forest Type.
(*b*) The Marshland Type.
(*c*) The Pine Barren Type.

[1] Schimper, Plant Geography, English translation, Oxford, Clarendon Press, 1903.

IV. THE GRASSLAND FAUNA.

(*a*) The Prairie Type.
(*b*) The Steppe Type.

V. THE PLATEAU FAUNA.

(*a*) The Cactus Desert Type.
(*b*) The Mountain Forest Type.

I. The Sub-Arctic Fauna.

This fauna may be regarded on the whole as a remnant of the once widely extended fauna of the last glacial period. Its characteristic forms are distributed around the margin of the polar basin in the Eurasiatic and North American land-masses and they become the distinctively Arctic species when dispersed along the maritime borders of the ice-caps.

(*a*) *The Barren Ground* or *Tundra Type* inhabits the circumpolar region north of the tree-limit. Among mammals such forms as the Barren Ground caribou (*Rangifer grœnlandicus*), the musk ox (*Ovibos*), now confined to the American land mass, the Barren Ground bear (*Ursus richardsoni*), the Arctic fox (*Vulpes lagopus*), the two genera of lemmings (*Myodes* and *Cuniculus*), Parry's spermophile (*Spermophilus empetra*), the red-backed mouse (*Evotomys rutilus*), and the Arctic hare (*Lepus glacialis*) are eminently characteristic.

The bird-life of the region is remarkable in that during the brief season of maximum sunlight certain species of plover, curlew, and other waders and waterfowl invade these desolate tracts in countless thousands, rearing their young and gorging themselves on the abundant food supplied by the cloudberry (*Rubus chamæmorus*), the crowberry (*Empetrum nigrum*), and other low, berry-bearing plants. The longspurs (*Calcarius lapponicus* and *C. pictus*), the snow-bunting (*Plectrophenax*), the redpoll linnets (*Acanthis*), the northern horned lark (*Otocoris alpestris*), the pipit (*Anthus rubescens*), the wheatear (*Saxicola œnanthe*), the willow ptarmigan (*Lagopus*), and the northern raven (*Corvus*), breed on the Barren Grounds.

(*b*) *The Tree-limit Type.*—This is an area of variable width lying between the Barren Grounds or Tundra and the northern border of the fully developed coniferous forest to the south. Its vegetational character is that of a stunted and scattered tree-growth due, as Schimper has observed, to the chilling effects of "dry winds during frosty weather." This enforces a low growth for protection against freezing.[1] Similar conditions are met with on mountain ranges (timber-line or alpine zone). This type is equivalent to the Hudsonian Fauna (a subdivision of the Boreal Zone) of writers. It has the features of a transition tract since certain forms of the typical coniferous forest range into it from the south, while such species as the wolverene (*Gulo luscus*), the ermine (*Putorius erminea*), and the gray wolf (*Canis griseus*) range across it into the Barren Grounds. It limits the northward dispersal of such mammals as the black bear (*Ursus ameri-*

[1] Schimper, Plant Geography, English translation, Oxford, 1903, p. 168.

canus), the lynx (*Lynx canadensis*), the fisher (*Mustela pennanti*), the red squirrel (*Sciurus hudsonicus*), and the woodchuck (*Arctomys monax*), while among birds the Barren Ground species above mentioned breed within its confines, and the Bohemian waxwing (*Bombycilla garrula*), the northern shrike (*Lanius borealis*), the rosy finch (*Leucosticte tephrocotis*), the orange-crowned warbler (*Vermivora celata*), yellow warbler (*Dendroica æstiva*), myrtle warbler (*D. coronata*), blackpoll warbler (*D. striata*), Wilson's warbler (*Wilsonia pusilla*), and the gray-cheeked and Bicknell's thrushes (*Hylocichla aliciæ* and *H. a. bickneli*), the olive-backed thrush (*H. ustulata swainsoni*) and the Alaska hermit thrush (*H. g. guttata*) extend their breeding range into it to a greater or less extent.

II. The Atlantic Forest Fauna.

The vast forested region of northeastern, north central, and northwestern North America that stretches from the Atlantic border to Alaska. The drainage of this great area is into the Atlantic and Arctic Oceans. Its northern portion is mainly a growth of conifers which fade away on the northern border into the tree-limit belt. This, the *Coniferous Forest Type* of fauna, is equivalent to the Boreal Zone and the Canadian Fauna of authors. South of this the evergreens give place to a mixed forest of deciduous hardwood species—oaks, ashes, elms, maples, birches, beeches, aspens, and numerous other kinds, its fauna forming the *Deciduous Forest Type*. This is the equivalent of the Transition Zone and the Alleghanian Fauna of writers. The difference observed by Merriam as to the temperature data between his Transition and Boreal Zones represents an undoubted causative element in the differentiation of the forest into its two types. It seems hardly credible, however, to suppose that this temperature difference has affected each organism of its fauna so profoundly as to produce a barrier. The fauna is essentially part of the forest, and its history and development pertains directly to the history and spread of this forest during the post-glacial period. A well-marked "forest fauna" is recognized as having existed during the last glacial retreat, following a tundra or arctic fauna, the remnant of which last is seen in the present Sub-Arctic Fauna as above described.[1]

(*a*) *The Coniferous Forest Type.*—The history of this faunal type is coincident with the spread of coniferous forests over a wide tract of country left bare by the shrinking of the ice-sheets at the close of the last glacial period (Wisconsin Stage). The fauna is characterized by its decided palearctic affinities. Like the Sub-Arctic Fauna, into which it merges along the tree-limit, many of its characteristic forms are but slightly differentiated from those of the Eurasiatic continent. Among mammals this palearctic element is found in such species as the moose (*Alces*), the wapiti (*Cervus*), the caribou (*Rangifer*), the black bear (*Ursus*), and others, while among birds such genera as *Otocoris*, *Corvus*, *Pinicola*, *Loxia*, *Carpodacus*, *Acanthis*, *Plectrophenax*, *Calcarius*, *Lanius*, *Bombycilla*, *Riparia*, *Petrochelidon*, *Hirundo*, *Anthus*, *Certhia*, *Sitta*, *Penthestes*, *Regulus*, and *Planesticus* are undoubtedly of palearctic origin.

[1] Osborn, The Age of Mammals, New York, 1910, p. 435.

This forest is part of the old world forest of similar vegetation types—*Pinus*, *Abies*, *Picea*, *Larix*, *Betula*, *Populus*, and *Alnus*—which extends around the northern land masses. Asia and North America were, as is well known, a continuous land in the Behring region. The development of this forest and its extension may have been partly favored by the moist climate due to the melting of vast masses of ice. Many of its faunal forms unquestionably extended their ranges with its advance over the uncovered territory and are now co-extensive with it; some forms seem to be indigenous to it in its American area (*Zonotrichia*, *Passerella*, *Junco*, *Perisoreus*, among birds), while numerous others have entered it from the American region farther south. This forest may have been developed in Mid-Pleistocene times, for the remains of numerous mammals of existing species, as well as of certain extinct forms, representing forest, meadow, and river types, have been found in deposits of this period in certain localities.[1]

(*b*) *The Deciduous Forest Type.*—The broad-leaved hardwood forest of North America is one of the most characteristic regions of the world. A marked divergence from old world types, both in flora and fauna, is noticeable as we proceed southward from its northern limit. This forest has probably existed from remote times, for the remains of such trees as the pin, white, and bur oaks, (*Quercus palustris*, *Q. alba*, and *Q. macrocarpa*), the beech (*Fagus*), the hazel-nut (*Corylus*), the plum (*Prunus*), the hickories (*Carya porcina* and *C. alba*), the thorn-tree (*Cratægus*), the Virginia creeper (*Parthenocissus*), and the pitch pine (*Pinus rigida*), have been found by Mercer in the deposits of the Port Kennedy Cave in Pennsylvania.[2] These are all existing species found in a deposit of the Mid-Pleistocene. It was probably developed in the unglaciated area and spread northward, following the belt of coniferous forest that skirted the retreating ice-sheets. Some of its more northern trees have mingled with the conifers, forming a mixed forest, quite characteristic of the borderland between the two types along the northern tier of States and in southern Canada. No hard and fast line of demarcation separates the faunas of these two forest types, there being some penetration of various forms from either side. A number of species of migratory birds do not extend their breeding ranges much beyond this deciduous forest; such genera, for example, as *Meleagris*, *Colinus*, *Zenaidura*, *Icterus*, *Sturnella*, *Pipilo*, *Passerina*, *Zamelodia*, *Troglodytes*, *Toxostoma*, *Vireo*, *Piranga*, and *Sialia*. Various genera of lizards and snakes are limited to this deciduous forest in their northward distribution—*Sceloporus*, *Eumeces*, *Coluber*, *Carphophis*, *Heterodon*, *Tropidonotus*, *Ophibolus*, *Cyclophis*, *Crotalus*, and *Ancistrodon*. Reptilian life as a whole is confined mainly to this forest in its northward dispersal, and here temperature has possibly a more or less direct influence, although the garter snakes (*Eutainia*) and the grass snake (*Liopeltis*) range well into the coniferous forest.[3]

[1] H. C. Mercer, *Jour. Acad. Nat. Sci. Phila.*, vol. XI, pt. 2, 1899, pp. 269–288. E. D. Cope, *Proc. Acad. Nat. Sciences Phila.*, vol. XI, pt. 2, 1876, pp. 193–267. H. F. Osborn, The Age of Mammals, New York, 1910, p. 469.

[2] H. C. Mercer, *ibid.*

[3] Arthur Erwin Brown, Post-Glacial Nearctic Centres of Dispersal for Reptilia, *Proc. Acad. Nat. Sci. Phila.*, vol. LVI, pt. II, p. 464, 1904.

III. The Coastal Plain Fauna.

The area occupied by this fauna is the Austral Zone of Merriam and later writers. It has been divided into an Upper and a Lower Austral on the basis of a difference in the aggregate of temperatures throughout the period of reproductive activity. In the eastern portion of the country the Upper Austral is synonymous with the Carolinian Fauna, while the Lower Austral is the Austroriparian Fauna or Region of earlier authors.

Geologically and topographically the area embraced in the Lower Austral (and extending into the Upper Austral on the eastern seaboard) corresponds to the *Coastal Plain*, a more or less flat country of Tertiary and Quaternary deposits, the latest addition to the southeastern portion of the continent. The Coastal Plain is marked on its inland Atlantic border, where these deposits rest against the older crystalline rocks, by a well-defined, though low, rise of land known as the "fall-line." It includes the widening southward expanse of slightly sloping plain from Southern New Jersey and Long Island (with narrow strips as far north as Cape Cod) that lies between the ocean and the Appalachian Piedmont. It is in reality the exposed portion of the continental shelf. Southward it extends to the low Gulf shores (Austroriparian) and passes around the southern foot of the Appalachians into the broad alluvial bottomlands of the Lower Mississippi and Ohio drainage basin. On the western side of the Appalachians the characteristic northern portion of the fauna (the Carolinian Fauna) has spread northward beyond the limits of the Coastal Plain proper to the Lower Lake Region as a result of the low relief of the land and the warm and moist summer influence of the Gulf of Mexico.

This Coastal Plain fauna presents three well-defined types incident to the diversity of soil and vegetation in different parts of the area—(*a*) *the Alluvial Forest Type*, (*b*) *the Marshland Type*, and (*c*) *the Pine Barren Type*.

(*a*) *The Alluvial Forest Type.*—A large portion of this Coastal Plain is a natural broad-leaf forest region, especially in the interior where it is covered by grand forests, of great diversity of species, over the wide alluvial bottomlands and lower hill slopes. Throughout these forests the magnolias and their allies are conspicuous, and among other characteristic species are the sweet gum (*Liquidambar*), the buckeyes (*Æsculus*), the persimmon (*Diospyros*), a great variety of oaks (*Quercus*), and many more quite as notable trees. Toward the south this forest extends over the Piedmont, mingling on the lower mountain slopes with the more northern deciduous forms of the Atlantic forest. On the Atlantic coast to the north this type of forest extends up the bottomlands of numerous river valleys as the Susquehanna, Delaware, Hudson, and Connecticut. Its distribution appears to be largely a matter of rich alluvial soils, although the climatic factors of heat and moisture undoubtedly exert a controlling influence in the northward range of certain forms of its vegetation. This coastal plain forest is, from the geographical point of view, a part of the general deciduous Atlantic forest of the eastern region. Its characteristic forms, however, and its soil

conditions, are in marked contrast to the more northerly type of tree-life on the uplands.

The fauna of this alluvial forest is exceedingly characteristic. It represents (together with the Pine Barren type) the great Ocmulgian center of dispersal for reptiles during post-glacial times.[1] Certain species of mammals, as the raccoon, the opossum, and the gray fox are much more abundant here than they are farther to the north, and some forms are eminently characteristic of its more southern portion (*Lepus aquaticus* and *L. palustris*, *Neotoma*, *Sigmodon*, etc.). Among birds the ivory-billed woodpecker (*Campephilus*), the ground dove (*Chamæpelia*), two genera of kites (*Elanus* and *Ictinia*) and the now almost extinct Carolina paroquet (*Conuropsis*) are confined to its southern portion. Such genera as *Guiraca*, *Helmitheros*, *Protonotaria*, *Icteria*, *Mimus*, *Thryothorus*, *Polioptila*, *Bælophus*, and the two American vultures (*Cathartes* and *Catharista*) do not range north of its limits, while a number of species are restricted in the same way.

(*b*) *The Marshland Type.*—The wide maritime marshes and lagoons that fringe the seaward edge of the Coastal Plain and the reed marshes and tracts of sedge grass that extend along the rivers and their estuaries form a habitat for a variety of species. Notable among birds are numerous waders and other waterfowl besides certain peculiar forms of sparrows (*Passerherbulus*) and the marsh wrens (*Telmatodytes* and *Cistothorus*). In winter many birds resort to these marshes from the upland districts and even further north, among them being certain Barren Ground species as the shore lark, snow bunting, longspur, and pipit. The short-eared owl (*Asio*) is also a denizen of these "flats." Among mammals the muskrat (*Fiber*) is quite characteristic of the river marshes, although its range is widely extended, reaching northward into the coniferous forest wherever a suitable habitat is to be found.

(*c*) *The Pine Barren Type.*—The extensive sandy tracts of the Coastal Plain are covered with a characteristic forest of pines, intermingled with several species of "scrub" oak, and known generally as the "Barrens" or "Pine Barrens" and in the south as the "Pine" or "Piney Woods." The area of Pine Barrens occurring in New Jersey have lately been very ably described by Mr. Witmer Stone who has shown "that we have in the New Jersey and North Carolina Pine Barrens the sand and bog elements of a widespread American Austral flora, which has been largely superseded by a more advanced element of similar origin over the rest of the Coastal plain, both elements being richer the farther south we go, while along the western edge of the coastal plain, more especially to the northward, a boreal element has spread down over the fall line to a greater or less degree."[2] The typical open pine forest is made up principally of the pitch pine (*Pinus rigida*) in association with the chestnut oak (*Quercus prinus*) and the scrub oaks (*Q. ilicifolia*, *Q. marylandica*, and *Q. prinoides*). The sassafras (*S. sassafras*), and the white birch (*Betula alba*) are also characteristic, as well

[1] Brown, ibid.

[2] The Plants of Southern New Jersey, by Witmer Stone; in the *Annual Report of the New Jersey State Museum for 1910;* Trenton, 1911, p. 112.

as an undergrowth of bracken (*Pteridium aquilinum*), sweet fern (*Comptonia*), smilax (*S. glauca*), wild indigo (*Baptisia tinctoria*), sheep laurel (*Kalmia angustifolia*), blueberry and huckleberry bushes (*Vaccinium vacillans* and *Gaylussacia baccata*), sweet goldenrod (*Solidago odora*), and other no less characteristic forms.

One of the most characteristic birds of this region is the prairie warbler (*Dendroica discolor*). Other species of birds find a congenial habitat here also, although by no means confined to such areas, as the thrasher (*Toxostoma rufum*), the whip-poor-will (*Antrostomus vociferus*), the chewink (*Pipilo*) and others. In the South Carolina "Pine Woods" certain species of sparrow (*Peucea*) are exceedingly characteristic and local.

The Coastal Plain as a whole presents a very remarkable history in the succession of its life forms. As stated above it is the latest area of land added to the eastern portion of the continent, and represents an uplift of marginal sea-bottom of Tertiary and Quaternary age. This uplift was probably a slow movement by the addition of beaches between which and the older land lagoons were formed and these later, through sod growth and soil accumulation, became the more permanent dry land of the Coastal Plain. Over this area the vegetation of the older land must have slowly spread as the soil conditions became suitable. The rivers, crossing this Coastal Plain from the Piedmont to the sea, spread rich alluvial deposits over their wide flood-plains and these meadow-soils became the site of the alluvial or bottomland type of forest with its characteristic flora and fauna. In the areas of Tertiary sands the characteristic types of the Pine Barrens developed. During the glacial period there was undoubtedly considerable crowding of types, both of animals and plants, throughout this coastal plain region, but its low relief, its mild climate, and the nature of its soils tended to foster a large southern element of the biota which probably spread to the north and east from some Gulf border center of dispersal. In its earlier history the Coastal Plain was first a fringe of beaches and lagoons, the habitat of species still found in these situations. Later this maritime fringe was filled in, here by sands, there by river alluvium, each slowly invaded by its characteristic biotic types, while a later line of marshes developed along its sea-front. It seems to me that we have in this coastal plain region remarkably characteristic types of vegetation and fauna clearly related to each other and to soil conditions, as factors in their distribution, rather than to an entire control by climate. Climatic conditions, as heat and moisture, are not to be ignored by any means, but as controling the distribution of animal species these factors are no more effective, undoubtedly in some cases less so, than are the character of the soil, influencing the nature of the vegetation, and the geological history of the land.

Other Faunal Areas.

The wide expanse of treeless, grass-covered country known as the "prairies" that stretches from the western edge of the Atlantic forest over the valley of the Mississippi, passing beyond the 100th meridian into the higher and drier

region of the Great Plains, conditions a very characteristic fauna. This I have called the *Grassland Fauna* from its most notable vegetation feature. Many forms of mammals, birds, and reptiles are peculiar to it. The effect of greater precipitation in its eastern portion (prairies proper) determines a more or less different type of flora and fauna from that obtaining over the arid steppe-like region of the so-called "Great Plains" of the West. Two types within this Grassland Fauna are thus defined—(*a*) *the Prairie Type*, and (*b*) *the Steppe Type*.

The above outline is more in accord with the conditions that prevailed before the opening up of the country by European settlement and the consequent widespread disturbance of the natural balance of existence in the adjustments between organisms and their environment. The cultivation of the land over the greater portion of the prairie country, incident to the growth of crops, has almost entirely exterminated the primitive flora in many places. Disturbances in the fauna must necessarily follow, some forms disappearing, others, like certain species of birds, increasing with greater food facilities from crop growth. The cutting off of wide tracts of forest in the eastern part of the United States likewise profoundly disturbed the faunal relations. Our fallow fields and pastures are in reality prairieland, and prairie types, both of fauna and flora, have migrated to these places from the similar natural region lying on the western edge of the forest. Many of our present field birds (*e. g.*, certain species of sparrows, meadow-lark, etc.) have undoubtedly thus found a habitat in our eastern fields and pastures since the earliest settlements. The opening of areas in the northern coniferous forest has had the effect of letting in more sunlight and has induced the spread of the deciduous type of woodland into these open spaces. This has been accompanied by a marked movement of certain species of the faunal type, notably among birds. Even some species of the alluvial forest type have invaded these areas of "second growth."[1]

A discussion of the faunal features of the western portion of the continent is not within the scope of this paper. I do not believe, however, that we are justified in assuming the presence of a continuous faunal zone extending across the entire land. The extension of the coniferous forest far into the northwest (Boreal Zone of Merriam and other writers) has certainly spread some of the species of its faunal type on the higher mountain ranges, but south of this (in the so-called "Austral Zone") there is a marked difference in specific forms, even to a difference in generic types in certain instances, between the eastern and the western portions of the continent. I have tentatively called this western element as a whole the *Plateau Fauna*, recognizing in a general way its division into two quite distinct *types* as conditioned by the broader features of vegetation dependent upon rainfall—(*a*) *the Cactus Desert Type*, and (*b*) *the Mountain Forest Type*—leaving the matter for some more competent investigator to analyze.

[1] See article by R. C. Harlow, Summer Birds of Western Pike County, Pennsylvania, *Cassinia*, 1906, pp. 16–23. Also Trotter, The Atlantic Forest Region of North America, *Popular Science Monthly*, Oct., 1909, p. 384.

In concluding this outline on the distribution of faunas in Eastern North America in relation to areas of vegetation I might briefly restate my belief that the present aspects of dispersal are a result of past conditions; that a fauna is the expression of certain adjustments between organisms and their environments, and that the most important direct factor in any environment is the nature of the vegetation which is conditioned by soil and by the climatic factors of heat and moisture. The faunal divisions outlined in this paper seem to me to accord more nearly with the observed facts. They at least rest on a natural relation of animal species to their present habitats and to the geological history of the land.[1]

[1] Trotter, *The Auk*, vol. XXVI, July, 1909, pp. 221–233. Also an article in *The Auk* for April, 1912, on The Relation of Genera to Faunal Areas; and in *Cassinia* for 1911, on The Frontier of the Carolinian Fauna in the Lower Delaware Valley. The above papers by the writer deal with features of faunal distribution that directly concern the matter of the present memoir.

The Relation of Smell, Taste, and the Common Chemical Sense in Vertebrates

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PHILADELPHIA
1912

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1. Introduction.

For some time past the term chemical sense has been applied as a general term to those senses in which the stimulus is due to the chemical action of environmental substances on the nerve terminals of the given sense organs. In man the chemical sense is well represented by taste and smell, but in addition to these, there is also an allied sense whose receptors occur on the exposed or partly exposed mucous surfaces, such as those of the nasal chambers, the cavity of the mouth, the moist surfaces of the eyelids, etc. The receptors on these surfaces are normally stimulated by the chemical action of the material in direct contact with them and they represent collectively a sense as distinct and well defined as smell or taste. This sense has been called by some recent workers the chemical sense or the undifferentiated chemical sense, but, for reasons that will appear later, I shall designate it as the common chemical sense and I shall use the term chemical sense as a generic term, including under it smell, taste, and the sense just alluded to. It is the purpose of this paper to discuss the relations of these three chemical senses in vertebrates, particularly that of the common chemical sense to taste.

In studying the chemical senses in vertebrates, my interest was directed especially to the common chemical sense for the reason that very little attention had been paid to it. For a long time investigators have known that the skin of a frog is very susceptible to chemical stimulation and the relation of this stimulation to acids, salts, etc., has been investigated by Braeuning (1904) and more recently by Cole (1910). The results of this work show some striking similarities between this form of stimulation and that of taste, and suggest at once that these two senses are nearly related. To ascertain something of this relation, studies on the stimulation of the skin of certain fresh-water fishes were undertaken and a brief preliminary statement of the work on the catfish, *Amiurus nebulosus*, was published by me in 1908. A year later Sheldon's extensive study of the common chemical sense of the dogfish appeared. Meanwhile I had carried out somewhat similar work on *Ammocœtes*, an account of which will be taken up at once.

2. The Common Chemical Sense of Ammocœtes.

The *Ammocœtes* upon which the following observations were made were obtained through the kindness of Professor S. H. Gage from Lake Cayuga, New

York. They were the young of a species of *Petromyzon*, probably land-locked, which at this stage could not be specifically identified (Gage, 1893, p. 456). They were extremely hardy and satisfactory for experimental work and I am under great obligations to Professor Gage not only for having called my attention to this animal but also for having provided me with a generous supply of living material.

In testing the *Ammocœtes*, they were placed individually in large, clean, glass dishes filled with tap-water and kept in a situation where the light was not bright, for these fishes are quite sensitive to illumination (Parker, 1905). After an individual had come to rest on the bottom of the dish, a pipette-full of distilled water was slowly discharged on a particular part of its body. If this operation called forth no movement on the part of the fish, as was usually the case, it was followed by a similar slow discharge on the same spot of the solution to be tested and the absence or nature of the response of the fish was then noted. The *Ammocœtes* was then rinsed in clean tap-water, transferred to another dish, and allowed to remain quiet for a period of not less than ten minutes before it was subjected to another test. Three regions on the body of the fish were selected for these tests, the mouth, the mid-trunk, and the tail. The rapid spread of the solution in the surrounding water prevented a more accurate localization.

The materials that were used for making the test solutions were such as have been frequently employed in testing the sense of taste in man: for a sour stimulus, hydrochloric acid was used; for an alkaline one, sodic hydrate; for a salty one, sodic chloride; for a bitter one, quinine hydrochloride; and for a sweet one, cane sugar. All the solutions were made in distilled water to which the *Ammocœtes* did not react; the acid, alkali, and salt solutions were made up as normal solutions and the quinine and sugar solutions as molecular solutions. Although all reasonable care was taken in the preparation of these solutions, it is obvious that the method of application of them—the discharge of a small amount of solution on a fish in a large volume of tap-water—was such that the solution would suffer a considerable and irregular dilution at the moment of application, so that the records obtained from the tests apply undoubtedly to weaker solutions than those recorded in the tables which really represent the strength of the solutions when they were in the pipettes. Notwithstanding this source of error, the responses of the individual fishes to stimuli assumed to be similar, were gratifyingly uniform. The results of these tests are summarized in Table I.

Solutions of hydrochloric acid of normal and decinormal concentration were stimulating to the mouth, mid-trunk, and tail of *Ammocœtes*, the three parts of the body tested. At dilution $n/40$, the mid-trunk was no longer stimulated, though the mouth and tail were so. At $n/80$ the tail was not stimulated, though the mouth was, and it was not until a dilution of $n/2{,}560$ was reached that the mouth ceased to be stimulated. These records show that, though the whole outer surface of the fish is stimulated by hydrochloric acid, the tail is more sensitive than the mid-trunk, and the mouth vastly more so than the tail As can be

seen in Table I, for each of the three parts of the body tested, a more concentrated solution of sodium chloride is needed for minimum stimulation than of hydrochloric acid. Hence the effective element in the stimulation by hydrochloric acid cannot be the chlorine ions, which are about equally numerous in the two sets of solutions dilution for dilution, but must be the hydrogen ions. These have been shown by Richards (1898) and by Kahlenberg (1898) to be responsible also for the sour taste in man.

TABLE I.

REACTIONS OF AMMOCŒTES TO SOUR, ALKALINE, SALTY, BITTER, AND SWEET SOLUTIONS APPLIED TO VARIOUS PARTS OF THE FISH'S BODY.

Reagent.	Part of Body Stimulated.		
	Mouth.	Mid-trunk.	Tail.
HCl *n*	Backed away.	Swam forward.	Darted forward.
HCl *n*/20	Swam away.	Moved slightly.	Swam forward.
HCl *n*/40	Swam away.	No reaction.	Swam away.
HCl *n*/80	Swam away.	No reaction.	No reaction.
HCl *n*/640	Swam away.	No reaction.	No reaction.
HCl *n*/1,280	Mouth movements only.	No reaction.	No reaction.
HCl *n*/2,560	No reaction.	No reaction.	No reaction.
NaOH *n*/10	Swam away.	Swam away.	Swam away.
NaOH *n*/100	Swam away.	Swam away.	Swam away.
NaOH *n*/500	Swam away.	No reaction.	Slight movement.
NaOH *n*/1,000	Swam away.	No reaction.	No reaction.
NaOH *n*/2,000	No reaction.	No reaction.	No reaction.
NaCl 2*n*	Swam away.	Swam away.	Swam away.
NaCl *n*	Swam away.	No reaction.	Swam away.
NaCl *n*/10	Mouth movements only.	No reaction.	No reaction.
NaCl *n*/40	Mouth movements only.	No reaction.	No reaction.
NaCl *n*/80	No reaction.	No reaction.	No reaction.
Quinine *m*/10	Swam away.	Swam away.	Swam away.
Quinine *m*/20	Swam away.	No reaction.	Swam away.
Quinine *m*/40	Swam away.	No reaction.	No reaction.
Quinine *m*/640	Swam away.	No reaction.	No reaction.
Quinine *m*/1,280	No reaction.	No reaction.	No reaction.
Cane sugar 2*m*	No reaction.	No reaction.	No reaction.

In a second series of tests on *Ammocœtes* in which a solution of nitric acid was used in place of hydrochloric acid, results indistinguishable from those in which hydrochloric acid was used were obtained. This is what was to be expected considering the close agreement in the chemical relations of these two acids.

An alkaline stimulus, a solution of sodic hydrate, was most effective, as Table I shows, at the mouth, somewhat less so on the tail, and least so on the mid-trunk. By comparing the reactions to sodic hydrate with those to sodic chloride, it can be shown by an argument analogous to that used for the acid reactions, that in the responses to sodic hydrate, the hydroxyl ions and not the sodium ions, are the cause of the stimulation. Essentially similar results to those obtained from sodic hydrate were produced by potassic hydrate.

For a salty stimulus a solution of sodic chloride was used; this was least stimu-

lating on the mid-trunk, more so on the tail, and most so at the mouth. No attempts were made in this case to determine which of the two ions was the effective one, but judging from what is known of the salty taste in man (Kahlenberg, 1898), it is probable that the chlorine ion, and not the sodium ion, was the stimulating material. It is, therefore, not surprising that tests with solutions of potassic chloride should give results indistinguishable from those obtained from sodic chloride.

To a solution of quinine hydrochloride the mid-trunk region of the fish was least sensitive, the tail more so, and the mouth very much more so. Thus, though a concentration of $m/20$ quinine was a minimum stimulus for the tail, the mouth could still be stimulated by a dilution of $m/640$. This general sensitiveness of *Ammocœtes* to bitter substances is in agreement with what Nagel (1894, p. 185) found for *Sygnathus* and *Lophius*.

For a sweet stimulus a $2m$ solution of cane sugar was used. No response could be called forth by this solution from any part of the fish.

These observations show that the exterior of *Ammocœtes* can be stimulated by sour, alkaline, salty, and bitter substances, but not by sugar. They also show that to chemical stimuli the mouth is most sensitive, the tail less so, and the mid-trunk least so. The distribution of this sensitiveness does not agree with that of the sensitiveness to light as already worked out (Parker, 1905), for the fish is most sensitive to light at the posterior end and less so on the trunk and head. This condition favors the view that the integumentary photoreceptors are distinct from those concerned with the common chemical sense.

3. The Common Chemical Sense of Amiurus.

Amiurus nebulosus is quite as satisfactory a fish for experimental purposes as *Ammocœtes* and a series of tests parallel to those carried out on *Ammocœtes*, were conducted for *Amiurus*. The results of these tests are summarized in Table II.

To solutions of hydrochloric acid, the tail and mid-trunk regions were about equally sensitive, but not so sensitive as the mouth. Similar reactions were obtained from normal solutions of nitric and of sulphuric acids, as well as from the less dissociated acetic acid.

To alkaline solutions, potassic as well as sodic hydrate, the tail and mid-trunk regions were equally sensitive, but neither was as sensitive as the mouth.

The salty solutions of sodic chloride and of potassic chloride were indistinguishable as stimuli, and in these instances as in the others, the mid-trunk and tail were much alike in their receptive capacity and clearly less sensitive than the mouth.

To quinine hydrochloride applied to the mid-trunk and tail, no response was given, though this reagent proved to be an unexpectedly vigorous stimulus for the mouth.

A $2m$ solution of cane sugar elicited no response from the tail, the mid-trunk, or even the mouth.

TABLE II.

REACTION OF AMIURUS TO SOUR, ALKALINE, SALTY, BITTER, AND SWEET SOLUTIONS APPLIED TO VARIOUS PARTS OF THE FISH'S BODY.

Reagent.	Part of Body Stimulated.		
	Mouth.	Mid-trunk.	Tail.
HCl *n*	Swam backward.	Swam forward.	Swam forward.
HCl *n*/2	Swam away.	Swam rarely.	Swam rarely.
HCl *n*/5	Swam away.	No reaction.	No reaction.
HCl *n*/20	Mouth movements only.	No reaction.	No reaction.
HCl *n*/40	No reaction.	No reaction.	No reaction.
NaOH *n*	Swam backward.	Swam forward.	Swam forward.
NaOH *n*/40	Swam backward.	Swam forward.	Swam forward.
NaOH *n*/50	Swam backward.	No reaction.	No reaction.
NaOH *n*/100	Mouth movements only.	No reaction.	No reaction.
NaOH *n*/1000	No reaction.	No reaction.	No reaction.
NaCl 2*n*	Swam away.	Locomotion.	Locomotion.
NaCl *n*	Mouth movements.	No reaction.	No reaction.
NaCl *n*/50	Mouth movements.	No reaction.	No reaction.
NaCl *n*/100	No reaction.	No reaction.	No reaction.
Quinine *m*/10	Swam backward.	No reaction.	No reaction.
Quinine *m*/20	Mouth movements only.	No reaction.	No reaction.
Quinine *m*/150	Mouth movements only.	No reaction.	No reaction.
Quinine *m*/200	No reaction.	No reaction.	No reaction.
Cane sugar 2*m*	No reaction.	No reaction.	No reaction.

As the foregoing account indicates, *Amiurus* differs from *Ammocœtes* in showing no difference in the sensitiveness of its tail and mid-trunk regions to chemical stimulation and in showing no response whatever to quinine when applied to the trunk and the tail. It agrees with *Ammocœtes* in not responding under any circumstances to a solution of sugar and in being more sensitive in the mouth region than anywhere else.

4. A MORPHOLOGICAL COMPARISON OF THE CHEMICAL SENSES IN VERTEBRATES.

Having shown that the head, trunk, and tail regions of *Ammocœtes* and of *Amiurus* are open to stimulation by relatively dilute solutions of substances such as are stimuli for the sense of taste in the higher vertebrates, it may next be asked what nervous mechanisms serve as receptors for these stimuli. This question must be approached experimentally and of the fishes that were studied by me, the only one well adapted to this purpose was *Amiurus*. The regions of the body of *Amiurus* that were most favorable for such work were the trunk and the tail. These regions are innervated by three sets of sensory nerves (Johnston, 1906): the spinal nerves concerned at least with the reception of tactile stimuli; the lateral-line branch of the tenth nerve distributed to the lateral-line organs and probably concerned with the reception of material vibrations of low frequency; and the lateral accessory branch of the seventh nerve supplied

to the gustatory buds which, as Herrick (1903) has shown, are distributed widely over the trunk of *Amiurus*. The question to be decided is what part, if any, each of these three systems of nerves plays in the reception of the stimuli recorded in the preceding section.

In selecting fishes for experimental work, individuals were first tested on the tail and trunk to ascertain that they reacted normally to acid, alkali, and salt solutions. After this had been determined, the fishes were divided into four lots, etherized, and operated upon as follows: in the first lot, the olfactory crura were cut; in the second, the lateral-line nerves; in the third the lateral accessory branch of the seventh nerve; and in the fourth both the lateral-line nerve and the lateral accessory. None of these operations were severe, for, in consequence of the comparatively superficial course of the nerves involved, any of them could be cut through slight incisions in the skin. The fishes were then allowed several days in which to recuperate and, after they had begun feeding regularly, they were tested with solutions of hydrochloric acid $n/2$, sodic hydrate $n/40$, and sodic chloride $2n$.

Fishes whose olfactory crura had been cut, showed the same sensitiveness on their trunks to acid, alkaline, and salt solutions that normal fishes did, thus demonstrating that the reactions to these substances were not dependent upon any accidental transfer of the stimulus forward to the nose. Fishes whose lateral-line nerves had been cut, were also indistinguishable in their reactions to acid, alkaline, and salt solutions, showing, as was to have been expected, that the lateral-line nerves are not involved in these responses. Fishes whose lateral accessory nerves had been cut, responded to the three stimuli in a way also indistinguishable from that of normal fishes. The same was true, as was to be expected, from fishes in which both the lateral-line nerves and the lateral accessories were cut. It, therefore, appears that the reactions in the trunk and tail regions of *Amiurus* to acid, alkaline, and salt solutions are not dependent upon the olfactory organs, the lateral-line nerves, or the lateral accessory nerves. Hence they must be due to the stimulation of the only remaining nervous mechanism, the ordinary spinal nerves whose free terminations in the epidermis must be regarded as the receptive organs for this sense. This conclusion, stated by me in a preliminary report (Parker, 1908*a*), has been abundantly confirmed by Sheldon (1909) in his study of the dogfish, much of whose integument is innervated by spinal nerves only. As the nerve terminals in the exposed and partly exposed mucous surfaces of the higher vertebrates, where the common chemical sense occurs, are, like those of the spinal nerves in the skin of fishes, free-nerve terminations, it is fair to conclude that this form of nerve ending is the characteristic receptive organ for the common chemical sense. Nerve fibers with such endings may be associated with any of the general cutaneous nerves of the head or trunk in vertebrates.

If the common chemical sense has for its receptors free-nerve terminations in the skin of *Amiurus*, what then is the significance of the taste buds found over the outer surface of this fish? Herrick (1903) has shown that *Amiurus* is

stimulated by a bait on the sides of its body as well as at its mouth. Tests carried out by me on specimens of *Amiurus* that had previously shown this reaction but in which the lateral accessory nerve had been cut, failed to elicit this response. With the loss of the lateral accessory nerve there was always a loss of response to ordinary bait, even though the fish remained reactive to acid, alkaline, and salt solutions. That this failure to respond to bait was not due simply to the shock of cutting nerves, is seen from the fact that when the lateral-line nerves were cut, nerves larger than the lateral accessories, the response to bait was still easily elicitable. These observations show that the lateral accessory with its taste buds as terminals adds considerably to the efficiency of the responses of *Amiurus* to such chemical materials as are contained in the food.

I endeavored to discriminate between the responses due to the chemical stimulation of the spinal nerves and to that of the taste buds by cutting the lateral-line nerves and destroying the hind part of the spinal cord thus leaving the posterior surface of the trunk and the tail innervated by the branches of the lateral accessory nerves only. Fishes operated upon in this way, however, did not respond to bait, nor to acid, alkaline, or salt solutions when applied to the integument in the cord-less region. It is my opinion, however, that this absence of response is due not so much to the ineffectiveness of the receptors of the lateral accessory nerve as to the complete paralysis of the musculature of much of the trunk and tail with which the fish habitually responds to such stimuli. From the observations of Herrick (1903) and from my own, it seems probable that the taste buds are in some way stimulated by sapid substances of significance as food and as a result the fish turns the head towards the part stimulated. According to my studies of the free-nerve terminals of the common chemical sense, these receptors are stimulated by materials more in the nature of irritants which lead the fish to avoid certain regions.

The receptors in the olfactory organs of *Amiurus*, like those of other vertebrates, are morphologically so distinct from the free-nerve terminals of the common chemical sense, and the taste buds and fibers of the organs of taste, that it is unnecessary to contrast them. Suffice it to say that olfactory cells, free-nerve terminals, and taste buds seem to be the appropriate receptors for smell, the common chemical sense, and taste respectively.

5. A Physiological Comparison of the Chemical Senses in Vertebrates.

In making a physiological comparison of the chemical senses in vertebrates, only a limited range of observations are available. The early records of Nagel (1894) on the stimulation of the skin of fishes by weak solutions of substances that are normal stimuli for the organs of taste are so incompletely described that it is often difficult to draw comparisons, at least of a quantitative kind, with the work of later investigators. My observations on the chemical sense of *Amphioxus* (Parker, 1908*b*) were scanty and my first report on the reactions of *Amiurus* (Parker, 1908*a*), really a preliminary communication, was necessarily

so brief that it could contain only an incomplete statement of results. The first exhaustive piece of work on the chemical sense in vertebrates was that by Sheldon (1909) on the dogfish. Sheldon's results are expressed in terms that admit of easy comparison with my work and are included in part in the following table which embraces observations on *Amphioxus*, *Ammocœtes*, and *Amiurus* from my own investigations, on *Mustelus* from Sheldon's work, and on man from several sources all of which, however, have been checked by me. The table shows for the three parts of the body of each of the five animals tested the weakest solution of a given substance that, so far as is known, will call forth a response.

TABLE III.

TABLE OF MINIMUM CONCENTRATIONS OF ACID, ALKALINE, SALT, BITTER, AND SWEET SUBSTANCES THAT WILL CALL FORTH RESPONSES FROM THE MOUTH, MID-TRUNK, AND TAIL REGIONS OF CERTAIN VERTEBRATES.

The records for *Amphioxus*, *Ammocœtes*, and *Amiurus* are based on observations by me (Parker, 1908[b], 1912); those for *Mustelus* on observations by Sheldon (1909); and those for man on observations by several workers, checked by me. The concentrations of the acid, alkali, and salt solutions are expressed in terms of a normal solution; those of the quinine and sugar solutions in terms of a molecular solution. N.R. indicates that even to a concentrated solution no reaction was given.

Regions of Body.	Animals.	HCl.	NaOH.	NaCl.	Quinine.	Sugar.
Mouth.	*Amphioxus*	*n*/500				N.R.
	Ammocœtes	*n*/1,280	*n*/1,000	*n*/40	*m*/640	N.R.
	Mustelus	*n*/75	*n*/10			N.R.
	Amiurus	*n*/20	*n*/100	*n*/50	*m*/150	N.R.
	Man	*n*/1,000	*n*/400	*n*/50	*m*/25,000	*m*/50
Mid-trunk.	*Amphioxus*	*n*/10				N.R.
	Ammocœtes	*n*/20	*n*/100	2*n*	*m*/10	N.R.
	Mustelus	*n*/50	*n*/20		N.R.	N.R.
	Amiurus	*n*/2	*n*/40	2*n*	N.R.	N.R.
Tail.	*Amphioxus*	*n*/100				N.R.
	Ammocœtes	*n*/40	*n*/500	*n*	*m*/20	N.R.
	Mustelus	*n*/40	*n*/20		N.R.	N.R.
	Amiurus	*n*/2	*n*/40	2*n*	N.R.	N.R.

A detailed inspection of Table III shows several significant features. None of the three fishes tested by me showed any response from any part of their bodies to sugar solutions even when of high concentration (2*m*), and in this respect my results agree with those of Sheldon (1909) on the dogfish. The statement made by Nagel (1894, p. 184) that a sugar solution will stimulate the mouth region of certain fresh-water fishes is put in so vague and uncertain a way that I am inclined to regard it with question and to agree with Sheldon (1909, p. 288) in believing that most fishes will be found to be unstimulated by sugar solutions. This condition has probably resulted from the fact that sugar is an unusual material in the environment of fishes. From this standpoint the possession of gustatory organs capable of being stimulated by sugar, as in man and other air-inhabiting vertebrates, may be regarded as a relatively recent acquisition and probably associated with the production and storage of sugar in terrestrial vegetation.

The fact that a sugar solution with a relatively high osmotic pressure does not stimulate the integumentary end-organs of certain fishes, though these organs are stimulated by solutions of acids, alkalis, salts, etc., of much lower osmotic pressure, shows conclusively that this form of stimulation is not due to osmotic pressure, but must be the result of the chemical action on the nerve-terminals of the dissolved substances, a conclusion in agreement with the well-founded view as to the stimulus for taste in man and other higher vertebrates.

Quinine, as a representative of the bitter substances, shows considerable diversity in its powers to stimulate. The mouth of *Amiurus* was stimulated by a solution as weak as $m/150$ and that of *Ammocœtes* by a still weaker one, $m/640$. Sheldon's records (1909) also show that the mouth of *Mustelus* is stimulated by a weak solution of quinine, though the weakest possible solution is not apparently recorded. When applied to the trunk and tail of *Mustelus* and *Amiurus*, quinine solutions called forth no response, though they were stimulating to the corresponding parts of *Ammocœtes*. This difference in the capacity of the integument of different species of fishes to be stimulated by quinine has already been recorded by Nagel (1894, p. 183). Notwithstanding these differences for the exterior of fishes, all thus far tested have been found sensitive in the mouth to quinine, even in relatively dilute solutions, though not so excessively dilute as can be tasted by the human being, $m/25{,}000$.

Of the inorganic stimuli, acids, alkalis, and salts, the least efficient judging from the concentration needed for the minimum stimulus, is salt. In only one location, the mouth region of *Amiurus*, was it possible to demonstrate a response from a solution of salt at a concentration ($n/50$) at which acid was ineffective. Aside from this exception, the relation of salt to acids and alkalis in the reactions of fishes is much the same as in human taste where the weakest solution of salt that can be tasted is $n/50$, very much stronger than the weakest alkali, $n/400$, or the weakest acid, $n/1{,}000$. Not only are the salt stimuli for the fish and for human taste thus quantitatively closely related, but since sodic chloride and potassic chloride give almost indistinguishable results with the fish, it is fair to conclude that the stimulus of the salt solution is the chlorine ion and not the sodium or potassium ions. This agrees with what is known of the salty taste in man where the chlorine ions are the effective elements and not the sodium or potassium ions which in the earthworm (Parker and Metcalf, 1906) are the real stimuli.

The acid and alkaline stimuli for the tail, mid-trunk, and mouth of the fishes are, as just indicated, usually much stronger than salt. In the matter of strength they form together a fairly well defined group in which in particular combinations acid is sometimes more stimulating than alkali or the reverse. In their effectiveness at low concentrations they agree well with the condition in human taste where the alkali is stimulating at a dilution of $n/400$ and the acid at one of $n/1{,}000$. Not only is there this general agreement from a quantitative standpoint, but, as already pointed out, the effective element in the stimulation of the

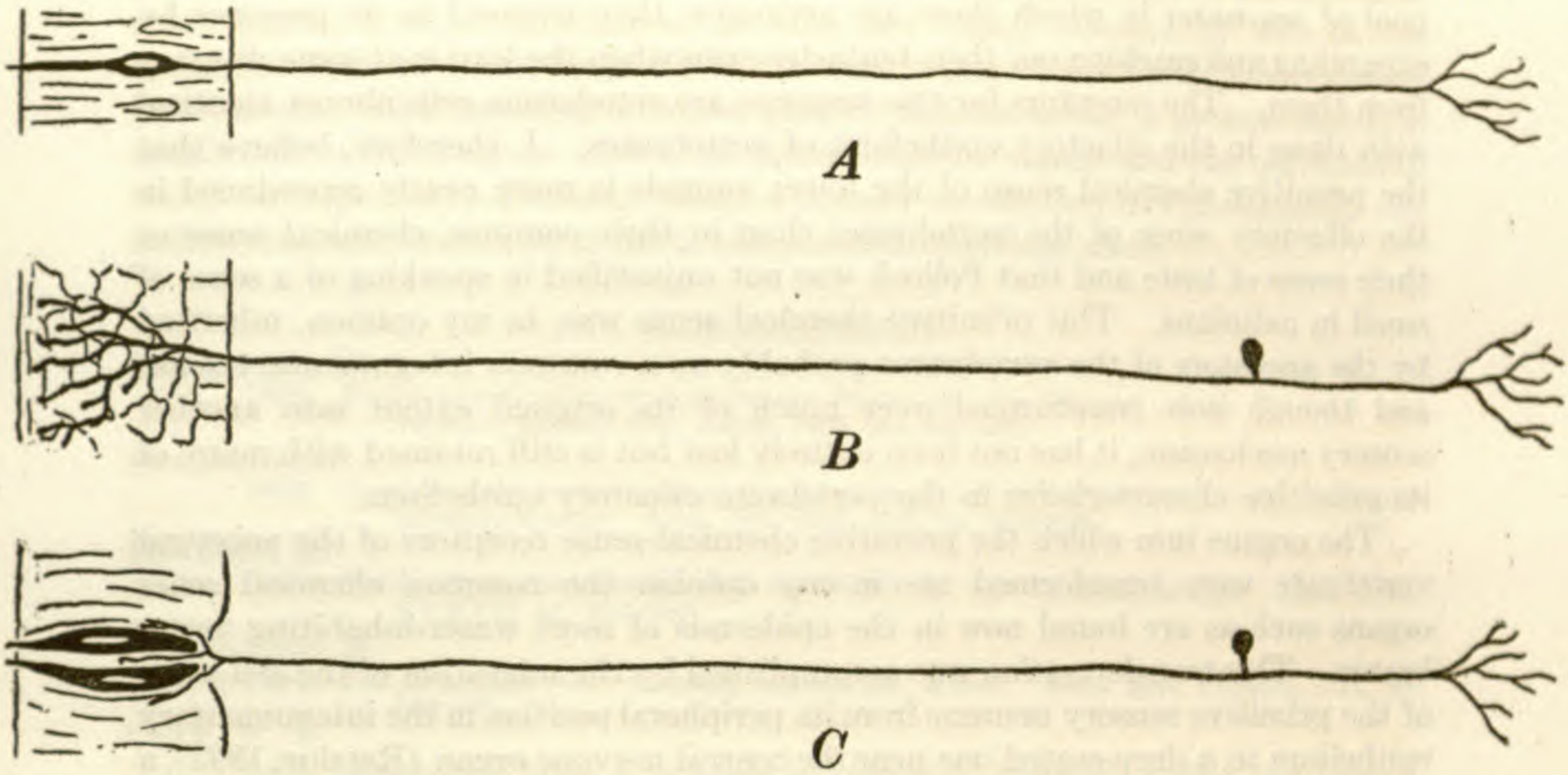
fish by acid is the hydrogen ion, the stimulus for the sour taste in man, and in the stimulation of the fish by alkali, the hydroxyl ion, the stimulus for the so-called alkaline taste in man. From these various comparisons, as well as from those mentioned in the preceding section, it must be evident that the common chemical sense and the sense of taste are closely related in vertebrate, in fact, they very probably overlap in a number of respects.

Although taste and the common chemical sense are undoubtedly closely related physiologically, from this standpoint both are sharply marked off from smell. The physiology of the olfactory organs in fishes and other water-inhabiting vertebrates has been a matter of much dispute. The idea, for which Weber is chiefly responsible, that solutions of odorous materials cannot be smelled when poured into the nasal chambers, led Nagel (1894) to conclude that the olfactory apparatus in the lower water-inhabiting vertebrates must be stimulated by solutions as the gustatory organ is, rather than as the olfactory organ is, and he, therefore, declared the nasal organs of fishes to be rather organs of taste than of smell. But the work of Aronsohn (1886) and the more recent contributions from Vaschide (1901), Veress (1903) and others, show that Weber's view is very probably incorrect and that odorous solutions can be smelled when properly introduced into the nose. Nor is it probable that the olfactory organs in air-inhabiting vertebrates are stimulated by any other means than by solutions, for even in such forms the olfactory epithelium is not really exposed to the air, but is covered with a layer of fluid in which any substances carried by the air must first become dissolved before it can reach the submerged olfactory cells. In the fishes and other water-inhabiting vertebrates where the olfactory surfaces are bathed by a current of water, the recent work of Baglioni (1909) and particularly that of my own (Parker, 1910, 1911) and of Sheldon (1911) have shown conclusively that these organs are stimulated much as they are in the higher vertebrates thus enabling the fishes to scent their food, an act that they could scarcely perform with only an organ of taste. It is, therefore, highly probable that the olfactory organs of all vertebrates, like their other chemical sense organs, are organs whose receptors are stimulated by solutions (v. Frey, 1904), but in such a way that they can be used as distance receptors and in strong contrast with the activity of the common chemical sense and particularly with taste in which the stimulus comes from only relatively strong solutions and the response elicited is concerned with more locally restricted actions than those called forth by smell.

6. Conclusions.

The conclusion of this discussion is to the effect that vertebrates possess at least three classes of chemical receptors, the olfactory organs, the organs of the common chemical sense, and the gustatory organs. The receptor of the olfactory organ is the olfactory cell from the base of which an olfactory fiber passes to its termination in the central nervous organ, the whole constituting an olfactory neurone (Diag. *A*). The olfactory apparatus is stimulated by extremely dilute

DIAGRAMS ILLUSTRATING THE RECEPTOR SYSTEMS OF THE FOLLOWING VERTEBRATE SENSE ORGANS: *A*, THE OLFACTORY ORGAN; *B*, THE COMMON CHEMICAL SENSE ORGAN; *C*, THE GUSTATORY ORGAN.



solutions and may, therefore, serve the animal as a distance receptor. Structurally and functionally this sense is in strong contrast with the common chemical sense and with taste. In the common chemical sense the nervous receptors are the epidermal free nerve-endings of a fiber whose cell-body lies in some deep-seated ganglion and whose proximal end is imbedded in the central organ thus constituting a sensory neurone of the first order (Diag. *B*). In the sense of taste a neurone like that described for the common chemical sense is associated distally with certain specialised gustatory cells forming taste buds (Diag. *C*). In both the common chemical sense and the sense of taste, the receptors are stimulated only by solutions very much more concentrated than in the case of the olfactory organ. Consequently the receptors of these senses are stimulated only when the source of the exciting material is in close contact with the sense organ itself, *i. e.*, they serve the animal chiefly as non-distance or surface receptors.

These three classes of sense organs have already been recognized by several investigators, notably Herrick (1908) and Sheldon (1909), and in their opinion the sense that I have called the common chemical sense is a primitive one from which the olfactory and gustatory senses have been differentiated. To me, however, it seems more probable that the olfactory sense more nearly represents the primitive chemical sense from which the common chemical sense and taste have been derived. I am led to this conclusion because the olfactory neurone presents a condition almost the exact duplicate of many primitive sensory neurones in the invertebrates and, further, because its sensitiveness to very minute amounts of substance and its capacity, therefore, to serve as a distance receptor

is also met with among the invertebrates. Thus Pollock (1883) has shown, and I have verified his observations, that when a piece of food is put in a natural pool of sea-water in which there are actinians, they respond to its presence by expanding and reaching out their tentacles even when the ford is at some distance from them. The receptors for this response are ectodermic cells almost identical with those in the olfactory epithelium of vertebrates. I, therefore, believe that the primitive chemical sense of the lower animals is more nearly reproduced in the olfactory sense of the vertebrates than in their common chemical sense or their sense of taste and that Pollock was not unjustified in speaking of a sense of smell in actinians. This primitive chemical sense was, in my opinion, inherited by the ancestors of the vertebrates probably as a common integumentary sense and though now transformed over much of its original extent into another sensory mechanism, it has not been entirely lost but is still retained with many of its primitive characteristics in the vertebrate olfactory epithelium.

The organs into which the primitive chemical-sense receptors of the ancestral vertebrate were transformed are in my opinion the common chemical sense organs such as are found now in the epidermis of most water-inhabiting vertebrates. This transformation was accomplished by the migration of the cell-body of the primitive sensory neurone from its peripheral position in the integumentary epithelium to a deep-seated one near the central nervous organ (Retzius, 1892), a migration which probably occurred under the influence of increasing metabolism at the proximal end of the neurone as the central nervous organ grew in complexity, and which may have resulted in a reduction of the sensitiveness of the distal end of the neurone in consequence of the withdrawal of the metabolic organ. The distal end, however, by forming a rich arborization among the cells of the thickening epidermis probably made good some of this loss and established itself as a fairly sensitive end-organ in a rich cellular environment, the epidermis. It is quite probable, as Botezat (1910) has suggested, that the real stimulus for this type of nerve ending may come quite as much from the activities of the epidermal cells as from the direct action of the external solution itself. In other words, the external solution may so influence the epidermal cells that the resulting secretions from them may come to be more important as a means of stimulating the true nervous end-organ than the external solution itself, *i. e.*, these nerve terminals may exhibit a form of indirect stimulation.

In the region of the mouth of the evolving vertebrate, these arborizations of the receptors for the common chemical sense probably became associated with particular groups of especially active epidermal cells which thus constituted the beginnings of a taste bud and established a set of peripheral secondary receptors whose sensitiveness was high because their metabolic efficiency, depending upon the nearness of their nuclei, was undiminished. Thus the peripheral sensitiveness which was reduced by the distal migration of the cell-body of the primitive sensory neurone may have been revived by the appropriation from the epidermis of certain secondary sensory cells whose secretory activity under the influence

of particular solutions may be the initial step in the stimulation of the real gustatory end-organs. If this view is correct, the most primitive of the chemical sense organs in the vertebrate is the olfactory organ, followed by that of the common chemical sense, from which the final organ in the series, the organ of taste, arose. This last step involves sensory appropriation, a process which is parallelled in the receptor system of the lateral-line organs and the ear, both of which have probably descended from a sensory mechanism morphologically not unlike that now known to occur in the common chemical sense.

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On the Supposed Tertiary Antarctic Continent

BY

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PHILADELPHIA
1912

ON THE SUPPOSED TERTIARY ANTARCTIC CONTINENT.

By Sir William Turner Thiselton-Dyer, D.Sc., LL.D., F.R.S.

Looking back, as I have recently had occasion to do, on the history of the gradual development during the last century of a rational theory of the distribution of life on the surface of the earth, it can hardly be contested that the germinal ideas have had their origin in the old world. But it must also be admitted—and it is not inappropriate on this occasion to recall the fact—that the ultimate shape they have assumed is largely due to a great American man of science.

Linnaeus laid it down that the individuals of a species must have had a common parentage. But a great difficulty arose in applying this principle when it was seen that individuals of the same species frequently occur in widely dissevered areas. One solution was to reject the principle and to assume, as has been done as lately as by Agassiz, that species have had "multiple origins."

Another solution first proposed by Forbes and adopted by Lyell and Hooker was to assume "the destruction of considerable areas of land." Writers on geographical distribution now occupied themselves, to use Darwin's words, "in sinking imaginary continents in a quite reckless manner" and in constructing land bridges in every convenient direction. They were brought back to the stern reality of fact when Dana in his *Manual of Geology* first made the unexpected statement: "The continents and oceans had their general outline or form defined in earliest time."

From this view Darwin, supported as he was by his own reflections, never deviated. Writing to Hooker in 1856 he said, "you cannot imagine how earnestly I wish I could swallow continental extension, but I cannot" (*Life and Letters*, II, 81).

In applying Dana's principle to the great northern and southern regions of the world's vegetation first indicated by Hooker, botanists may admit that as regards the former, known means of physical transport may afford a sufficient explanation, but it must be conceded that as regards the latter they are quite inadequate. The northern temperate flora occupies large continuous surfaces; the southern is distributed over widely dissevered areas—Australia, South Africa, South America. Yet each with its own characteristic facies contains common elements, the significance of which it is impossible to ignore, pointing as they do to a common origin. A few examples must suffice. Few families in the vegetable kingdom are more sharply defined than *Proteaceæ;* they have their headquarters in Australia and South Africa, *Banksia* for example in the one and *Protea* in the other may be taken as examples; they are more feebly represented by the lovely

Embothrium and three other genera in South America; but though they reach in the Old World as far north as Abyssinia, no representative crosses the northern tropic. *Mutisiaceæ*, a remarkable tribe of *Compositæ*, reach Japan and California but are characteristically southern, with headquarters in South America; *Oldenburgia* represents them in South Africa and *Trichocline* in Australia. *Restiaceæ*, closely related to the ubiquitous sedges, are equally localized in South Africa and Australia with a single South American representative, a *Leptocarpus*, in Chile. Perhaps the most striking case of all is *Ravenala* with only two species, one in Madagascar, the other in Brazil.

In the face of these and other facts it is not to be wondered at that many botanists have, like Darwin, thought "that there must have existed a Tertiary Antarctic Continent from which various forms radiated to the southern extremities of our present continents" (*Life and Letters*, III, 231).

But if such a continent ever existed it may be equally contended that it did so at a much earlier age, for the gradual investigation of the Glossopteris flora reveals the same facts as regards its distribution as are shown by flowering plants in the Southern Hemisphere at the present time; it has been detected in fact in Brazil, in South Africa, in Southern Australia and in the Indian Peninsula. Gadow therefore postulates the existence of a "great Permo-carboniferous Gondwana land in its fullest imaginary extent, an enormous equatorial and south temperate belt from South America to Africa, South India and Australia, which seems to have provided the foundation of the present southern continents, two of which temporarily joined Antarctica" (*Darwin and Modern Science*, p. 334).

Wallace has stated forcibly the arguments against the vast changes in the surface of the earth which the elevation and submergence of such an area involves. For the distribution of land and water is antipodal in the two hemispheres, and it may be concluded that elevation in the one would be compensated by submergence in the other, and of this there appears to be no evidence. On the other hand the researches of the Challenger Expedition have shown that the oceanic depths are covered by oozes which bear no resemblance to any rocks composing existent land masses. And Geikie concludes "that the present land of the globe, though consisting in great measure of marine formations, has never lain under the deep sea." Each successive line of argument adds additional force to Dana's original position and leaves the botanist still in search of a solution of his problem. It is to be noted that Hooker gradually abandoned his belief in continental extensions which he described in 1879 as "the forlorn hope of the botanical geographer."

A problem of exactly the same kind presents itself to the zoologist. Marsupials exist in America as well as Australia and tapirs are found in Malaya and tropical America. But fossil remains prove that these dissevered habitats are but the isolated survivals of a former wide extension in the northern hemisphere. If then the explanation is to be found in a common source of origin in the case

of animals in existing northern continental rather than in a hypothetical southern continental land, it can hardly be refused to extend it to plants as well.

Unfortunately the fossil remains of flowering plants can rarely be interpreted with any certainty. The appeal to paleontological evidence which is in cases such as these which have been quoted sufficiently conclusive, is in respect to plants almost wholly negative. Heer and Ettingshausen thought they had obtained conclusive proof of the existence of *Proteaceæ* in eocene and miocene formations in Europe. But Bentham, after a prolonged study of the existing representatives of the order and a careful consideration of the supposed fossil evidence, was forced to the conclusion that it had broken down.

If, however, we go back to an earlier period, the Jurassic, and turn to *Coniferæ*, the structures of which lend themselves better to recognition in the fossil state, we find in *Araucaria*, a genus now represented by a few species in both divisions of the southern hemisphere, abundant evidence that it was once widely dispersed in the northern. Going back earlier still, the strong case which has been made out for Gondwana land is perceptibly weakened by the discovery of remains of the Glossopteris flora in Russia. An economy of hypothesis is better served by assuming a northern origin and a dispersal southward than by calling into existence a vast territory from the Indian Ocean.

A more serious difficulty is to account for the presence in the widely dissevered tropics of the Old and New World of identical groups of a higher order although differing in their present representatives, and still more for such an extreme case as the two species of *Ravenala*. This it must be confessed would be inexplicable on Dana's view were it not for the apparently inevitable evidence for the existence in miocene and probably earlier times of a subtropical climate and vegetation in the Arctic regions. Purely tropical types would have under such conditions a more northern range and their interchange between the two Worlds would not be impracticable.

The classical researches of Hooker first recognised the "continuous current of vegetation" southward at the present time. He indicated three types each with its own character: the Scandinavian which reaches Tasmania; the Persian, Australia; and the Himalayo-Malayan, Polynesia.

Half a century has nearly elapsed since Dana laid down his memorable principle. Time has strengthened and in no way diminished its force. But though adopted by Darwin and by Wallace it is still ignored by those who prefer facile speculation to the sober contemplation of established facts.

Mollusk Fauna of Northwest America

BY

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PHILADELPHIA
1912

THE MOLLUSK FAUNA OF NORTHWEST AMERICA.

By William H. Dall., A.M., Sc.D.

The fauna of the northwest coast of America first began to be known to men of European origin through Bering's voyage in 1740, as reported by the naturalist Steller, who accompanied the expedition. But the difficulties of transportation across the whole breadth of Asia precluded the arrival of specimens in Europe for many years. On the west coast of middle and south America, collections were made by Dombey in 1778, and doubtless shells were sent or brought to Europe from this region by Spanish seafaring men long before; but the first publication on them was by Lamarck in 1819, who also described specimens from the collections of Humboldt and Bonpland, made in 1803.

The first published record of shells from the northwest coast is found in Thomas Martyn's *Universal Conchologist*, of which some plates were issued as early as 1782, but which was definitely offered to purchasers in 1784.

Cook's expedition to the Pacific returned to England in December, 1780, and shortly thereafter the private collections of the officers and sailors, comprising many new shells, were sold or given away, and passed into the possession of dealers and naturalists in 1781. Martyn purchased many of them and illustrated them in the most exquisite manner in the 161 plates of which his *Universal Conchologist* is composed.

In 1786, Captain George Dixon, trading on the coast, visited Cook's Inlet and obtained from the sandy shores quantities of a large bivalve which was used for food by his party, and afterward was figured under the name of *Solen patulus* in the account of his voyage published in London in 1789. Captain Dixon therefore was the first conchologist to collect in person on the northwest coast. In 1880, the present writer visited Dixon's original locality, Coal Harbor, Port Graham, and found his shell still abundant there.

From this time forward numerous traders and explorers visited the coast and contributed in greater or less degree to the store of shells from the region which reached the museums and students of Europe.

The most conspicuous of these during what may be called the Martynian period of some forty-five years from the return of Cook's expedition, were the voyages of the Russian navigator Kotzebue, with his naturalists Eschscholtz and Chamisso, who added greatly to our knowledge, and were followed by the British, Beechey and Belcher, whose collections were well illustrated by Gray and Sowerby.

The next period, which may be called after its pioneer, the Nuttallian period, covers about thirty years, and exhibits very great activity in collecting and de-

scribing the shells of the coast. The work of Thomas Nuttall, the botanist, extending over the years 1834 and 1835, resulted in a large collection of shells as well as plants, and the Academy of Natural Sciences of Philadelphia had the privilege of publishing a paper by Conrad in 1837, in which a majority of them were described and figured. This was the first American contribution to the conchological history of that prolific coast.

In the report of the voyage of La Perouse the first brachiopod of the region is figured, and in similar publications by Hinds and Belcher many northwest coast shells are described and beautifully illustrated.

The first attempt to monograph the shells of the Russian portion of the coast was by the celebrated explorer and scientist, von Middendorff, in 1847–51, and his work still remains for the student of the fauna an indispensable classic. Special collections by a preparator of the Imperial Academy, Elia Vossnessenski, sent out for the purpose, aided in making it more nearly complete. About the same time that conchological enthusiast, J. P. Couthouy, obtained a position on the United States Exploring Expedition under Wilkes, with the special object of utilizing to the utmost the opportunities for exploration which it afforded. Couthouy was a man of progressive ideas and methods, with much artistic ability. He planned to make the collection unique in the accuracy of its localities and in the profusion of drawings made from the living animals of the species collected. In each jar from hundreds of stations was placed a tag of tinfoil with a number stamped upon it corresponding to the number in the notebook of the collector. For four weary yet interesting years he toiled incessantly and sent back to Washington the largest collection ever made by a single expedition up to that time. As the boxes arrived in Washington they were sent to the Patent Office where a retired clergyman had been appointed to take care of the collections until the expedition returned. Observing that the presence of lead in the tinfoil tags was whitening the spirits in some of the jars, this enlightened custodian carefully went over them all and removed every tag, and with them all hope of ever positively identifying the contents of the jars with locality or notes. The tags were carefully preserved in an empty jar, where many years ago I saw them, kept by Professor Baird as a horrible example of ignorance and incapacity.

When Couthouy returned he found his work of years ruined, and wounded beyond endurance, abandoned the enterprise. Years afterward, Dr. A. A. Gould was prevailed upon to save what he could from the wreck, and this is recorded in his report on the "Expedition shells."

In 1848–50, Herr Reigen, a Belgian collector, resident at Mazatlan, Mexico, made an enormous collection of the local shells, which, when packed, occupied, according to Dr. Philip P. Carpenter, 460 cubic feet of space. This collection, perhaps the largest ever made at one locality, on the collector's death in 1850, mostly came into the possession of a dealer in Liverpool, where, excluding the more bulky shells, it was acquired by Dr. Carpenter and formed the basis of his well known *Mazatlan Catalogue*, printed 1855–57, and distributed by the author with many duplicate collections.

Work on this catalogue inspired Dr. Carpenter with the happy idea of collecting the scattered data in regard to the shell fauna of the west coast of America into a single volume. With this work was ushered in what we may justly call the Carpenterian period, extending from 1855 to 1877, the year of his lamented death.

Dr. Carpenter made his first report to the British Association for the Advancement of Science in 1856. The reputation acquired from these two important publications led to an invitation to visit the United States, to deliver a series of lectures on mollusks at the Smithsonian Institution, and to classify and arrange the collections at Washington belonging to the nation. Subsequently Dr. Carpenter moved to Montreal, where his own collection now forms part of the museum of McGill University, and where he continued his studies until death interrupted them. As the chief expert in the knowledge of this special fauna, he was called on by all those interested to assist in identification of their collections.

Through the influence of the Smithsonian the reports on government collections from that region were entrusted to him. The PROCEEDINGS of the Academy of Natural Sciences of Philadelphia for 1865 contains the preliminary report on the shells of the commission on the northwest boundary of the United States, collected by Dr. Kennerley. The State Geological Survey of California under the direction of Prof. Josiah D. Whitney, ably assisted by Dr. J. G. Cooper as zoologist, put all its material into Dr. Carpenter's hands and several important papers containing part of the results were published by the California Academy of Sciences. Meanwhile, the supplementary report to the British Association had been made in 1864, bringing the results of all these activities up to date. This report, with a reprint of many smaller papers relating to the same general subject, was republished in 1872 by the Smithsonian Institution and has formed an indispensable handbook for all students of the fauna. Beside these researches, Dr. Carpenter worked for years on a monograph of the Chitonidæ, or coat-of-mail shells, in which the region is extraordinarily rich. This he did not live to finish, but his manuscripts were ably edited, supplemented, and brought up to date by Dr. H. A. Pilsbry, and published as a part of Tryon's *Manual* under the auspices of the Conchological Section of the Academy of Natural Sciences of Philadelphia, in 1892–1894.

During the period when Carpenter was working on the fauna many collectors, through the Smithsonian Institution, contributed to his material for study, among many others the present writer, and Dr. R. E. C. Stearns. Mr. J. G. Swann, a teacher on the Makah Indian reservation at Neeah Bay, and afterward agent there, enlisted the services of his pupils in collecting on the adjacent beaches with great success, and their labors are remembered, in the quaint Latin used in Dr. Carpenter's publications, as those of "*Swannii Indianuli.*"

After Dr. Carpenter's death a new epoch in the exploration of the fauna

was begun when the Steamer *Albatross*, of the U. S. Fish Commission, came "round the Horn" and began to explore the deeper waters of the coast. Her dredgings have extended from Patagonia to Bering Sea, and from Panama to the waters of Japan and the Okhotsk Sea. The collections of mollusks were merely incidental to her other work but aggregate a very large total, and comprise much very precious material. The collections of the Revenue Marine in the Bering and Polar Seas south and north of Bering Strait deserve mention, and also those made by members of the U. S. Geological Survey, both of recent and Pleistocene or even older material.

The present writer during eleven years spent on the coast of Alaska in the U. S. Coast Survey hydrographic work, made a very large collection, now in the National Museum, which also acquired the collection of the late Dr. R. E. C. Stearns.

This material, supplemented by the generous aid and donations of many private collectors, has resulted in bringing together a collection not only more extensive than that in any other museum, but it may also be said more extensive than that of all other museums put together, for this particular fauna. It is hoped within a reasonable time to make it the basis for a general manual of northwest coast shells, though there is no doubt that the improved methods of collecting, the increased number of collectors and the more thorough exploration of all parts of this immense stretch of coast, will furnish a supply of novelties for many years to come.

While the study of these collections is far from complete, yet a great deal of work has been done upon them and it is possible to formulate some tentative general conclusions in regard to the Pacific coast faunal relations, as indicated by both the recent and fossil material.

One of the most interesting facts brought out by the *Albatross* dredgings in the Okhotsk and Japan seas is that the two faunas, the American and Asiatic, are almost perfectly distinct. Excluding the polar fauna of the Arctic seas, which is limited in species and circumboreal in distribution, and which sends a few members southward on both coasts, the number of species common to the opposite shores of the Pacific is astonishingly small. Even the narrow channel of Bering Strait divides many of the species, a fact which may be connected with the southward current of cold water which washes the Asiatic coast from Bering Strait to the Kurile Islands, while on the American side the drift is of water warmed over the shallows of that part of the sea and in Norton and Kotzebue sounds, and moved northward along the coast by the tides and a combination of other physical factors.

The vast submarine plateau, which occupies the northeastern portion of Bering Sea and is covered by only 100 feet of water or less, has a special fauna of its own, differing from the shore fauna nearest to it and having many peculiar species. The gap between it and the shore fauna may perhaps be connected with the action of ice in winter near the shores, which does not operate in water

more than 24 feet deep. The plateau fauna is remarkable for its fine and singular forms of *Chrysodomus*, *Volutopsius*, and other Buccinidæ.

The Arctic or circumpolar mollusk fauna extends to the south as far as the southern limit of floating ice in winter. Many other animals are similarly limited; the fur seal and the cod keep to the south of this line.

It is perhaps a little early to do more than roughly indicate the limits bounding the faunal districts of the coast. In the north we have the Aleutian subfauna from the Gulf of Alaska westward; to the eastward the Oregonian district reaching as far south as Point Concepcion. The Californian, Gulf, and Panamic districts follow, succeeded by the Peruvian and Magellanic.

On the Asiatic side, the Okhotsk Sea has a special fauna which extends throughout the sea itself and from the southern part of Kamchatka to northern Japan.

On the American coast between the Gulf of Alaska and Dixon Entrance, especially in the narrow passages entering the mainland behind the fringing archipelago and fed by many glaciers, are what appear to be more or less isolated colonies of more northern aspect, perhaps remnants of a fauna generally distributed during the colder glacial epoch.

Coincidently, the warmer waters of the open seas permit a northward extension of southern animals on the outer edge of the archipelago, where a number of species of predominantly more southern habitat have been traced as far north as the entrance to Sitka Sound, though they do not enter the colder waters of the Sound itself.

A striking instance of the importance of sea temperatures in determining the range of marine animals is afforded by the distribution of *Turcicula bairdii* Dall, a large Trochid which was first dredged by the *Albatross* in 400 fathoms in the Santa Barbara channel of California, and later found in southern Bering Sea in 25 fathoms; the sea temperature being the same in both cases.

The Pliocene period here, as on the eastern coast of North America, was characterized by a milder climate than that which immediately succeeded it. Thus the Pliocene beaches of Nome, Alaska, contain a fauna which by the species in it no longer native to that region but now living elsewhere, must have approximated to that at present found in northern Japan and the Aleutian Islands. One might infer that there was also at this time a closer connection with the seas of northeast America than exists at present, since we find fossil in the Pliocene of Sankaty Head, Nantucket, two or three species, which at present live only in Bering Sea. A fine *Littorina*, of the *obtusata* type now confined to the Atlantic ocean, is also found fossil in the Nome Pliocene. The evidence of the beaches indicates a persistent, if not absolutely continuous, moderate elevation of the shore in this vicinity from the Pliocene to the present time.

If we may take as evidence that a particular area formed a center of distribution of certain organic types, the fact that paleontology shows that those types existed in that area during a period geologically long; that at present the

types are represented by a much greater number of species and profusion of individuals in that area than elsewhere; and that as we increase our distance from the area mentioned the types are represented by fewer and less varied forms; then the northwest coast faunal region is undoubtedly the center of distribution for such types as *Buccinum*, *Chrysodomus*, *Liomesus*, *Beringius*, and *Nucella*, all of which are represented there, as in no other region. The richness of the fauna is particularly striking when it is compared with that of the northeast coast of the continent.

There are very few if any species which can be traced with probability as immigrants from the Southern Hemisphere or the Atlantic. The Indo-Pacific admixture in the West American tropical fauna is almost negligible. So far as yet known the proportion is less than one tenth of one per cent.

So far as paleontological evidence is yet available, the intimacy between the faunas of the Panamic and Caribbean seas which existed in the Oligocene rapidly diminished after their separation by the elevation of the isthmus between them; nearly all the characteristic west coast types becoming extinct on the Atlantic side before the present epoch. Many genera originally common to both oceans are now represented by analogous species on the Pacific side, but less abundantly or not at all on the Atlantic shores.

Taking a broad general view of the west coast mollusk fauna of North America as a whole, we come to the conclusion that it is of all marine mollusk faunas the least intimately related to any other existing fauna. This may be supposed to be due to the broad expanse of ocean separating it, except at its northern and southern extremes from any other land, and to the necessarily slow rate of distribution of molluscan life over the floor of the deep sea.

The Relation of Plant Protoplasm to its Environment

BY

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PHILADELPHIA
1912

THE RELATION OF PLANT PROTOPLASM TO ITS ENVIRONMENT.

By John Muirhead Macfarlane, D.Sc.

In discussions regarding the origin and the relations of plant and animal cells to their environment, we too often select and speak of the more highly organized groups of plants and animals, or of these when in the actively vegetating and reproductive phases. And so we treat of cells that consist of the more generalized substance *protoplasm* alongside the more specialized substance *nuclear chromatin*, while we ordinarily study both in their most active state.

But alike for the primitive origin of plants and animals, their means of dissemination and perpetuation, as well as their relation to higher forms, it is of prime importance that we should try to get exact conceptions as to the most primitive and most simple organisms, as well as the endurance capacity of the highest types now living.

The aim of this paper is to record observations, and to bring together results, that may aid us in our estimation of the life capacities of plant protoplasm. The writer has also brought together results, which he hopes to publish in time, bearing on animal protoplasm, and which show that between both there is a fundamental agreement.

While we would by no means consider that protoplasm is so simple a substance that it can, or probably will, be generated by the physiological chemist, on a few minutes' or a few hours' notice, we would equally consider that all experimental evidence indicates that it primitively originated by slow natural processes, at a stage in the world's history, when physico-chemical surroundings had become such as to favor actions and reactions that gradually resulted in its formation.

It becomes then a matter of high value to ascertain whether evidence can now be secured, that would aid us toward a solution of its mode of origin. In such an inquiry also, it will readily be conceded that the four great environmental factors which determine synthetic and analytic activities are temperature, light, electro-chemical action and water supply. Further if living organisms are to aid us in our interpretation of past existence, our studies should begin with those simplest forms that consist of non-nucleate protoplasm. In attempting to follow out such a line of inquiry, some biologists have emphasized the importance of types like the Myxomycetes and the Lobosa, as being irregular protoplasmic aggregations which ingest food, often in a solid state. But apart from the beautiful nuclei and nucleoli that these show, as well as the karyokinetic phases exhibited in their cell division, we would regard their mode of food absorption as a specialized—not a primitive—one. Even did we know more accurately regarding such forms as *Chlamydomyxa* amongst plants, and *Proto-*

myxa amongst animals, we are unable to view these as surviving remnants of primitive types.

At this stage then we would suggest that far too little emphasis has been placed on, and too little experiment has been conducted to extend, the value of Traube's discoveries regarding colloid membranes and their enclosures. Here we believe exists a wide field for study, in which the physico-chemist and the physiologist might join their experimental and observational efforts with happiest results.

Let us turn our attention now to that still fairly large group of organisms the Schizophyceæ, Protophyceæ, Cyanophyceæ or blue-green algæ. The writer's more minute attention was directed to them when his deceased student and colleague, Dr. O. P. Phillips, carried on careful and extended observations, that have already been published (1). Since then he has advanced his knowledge of them along various lines.

Though synonymy and a tendency to variation, or possibly to pleomorphism, have given rise to a copious nomenclature,we are probably justified in considering the group to be made up of about 80 genera and close on 650 species. Of these 518 species are freshwater or terrestrial, 21 are brackish water, and 111 are salt-water or found in saline lakes. It should further be noted that not a few of the species exhibit an environmental adaptability to fresh and brackish, or to brackish and salt water, or even to the first and last that is in marked contrast to the behavior of most of the higher plants. We would interpret such distributional features as an indication that the group originated in, and still largely adheres to, a freshwater life, though as we shall presently indicate, the term "freshwater" requires to be liberally interpreted.

In form they vary from simple spherical cells that are embedded in abundant mucilaginous sheaths or layers, like *Glœocapsa* and *Aphanocapsa*, to others like *Nostoc* that form connected threads of subspherical or oval cells embedded in mucilage, and again to types like *Oscillatoria* and *Rivularia* that are elongate usually branching filaments, enclosed in rather thin gelatinous walls, and made up of similar or dissimilar cells. In the color of the cell contents the above form-groups may vary from yellow to brownish-yellow, reddish or purplish-brown, red-green, purple-green or blue-green, more rarely a rich olive-green. Fairly well correlated with advance in color and in general morphology, a similar progress is shown in cytological detail. In simpler types like *Glœocapsa* and *Aphanocapsa*, the cell-contents consist only of an outer colored zone of very finely granular protoplasm, which holds the pigment above noted, and which has been termed the chromatophore. Within this is a more coarsely granular mass, which under high magnification suggests the existence of a finely reticular substance, that carries definite bodies of varying size and refraction.

As we advance through Nostocaceous types, the main difference is that reserve substances—chiefly glycogen—are not unfrequently stored in each cell, but more importantly we note that definite refractive granules, which absorb

chromatin stains, become more and more prominent, though irregularly and often widely scattered through the cell. In the higher thread forms like *Oscillatoria* and *Lyngbya* these granules are united into loosely coiled granular threads of chromatin, which we regard as a primitive and evolving nuclear structure.

The geographical distribution of the genera and species is noteworthy, for it is safe to say that in no other group—except possibly the mosses and to a less extent the ferns, both with small light spores—are so many species included that show an extended, often even a world-wide distribution. It is rare indeed, also, amongst higher or nucleate plants, that the same genus may include species some of which are freshwater, some brackish and some marine. But we need merely name the genera *Glæocapsa*, *Merismopædia*, *Oscillatoria*, *Symploca*, and *Anabæna* as a few amongst others that are illustrative.

All of the above-mentioned details and others to be presently considered, strongly suggest that we have here to deal with a primitive, possibly *the most primitive* plant group now surviving. In further support of this, and at the same time opening up, as we believe, a highly suggestive line of investigation, is that morphologically diverse but physiologically similar series of the group, that may appropriately be called the "thermophile Schizophyceæ." This includes some 17 genera and 40–41 species which are found at the present day over the entire world, and inhabiting warm or even hot waters of geysers, hot springs, or warm mineral fountains.

When the suggestion was first made, now nearly a century ago, by a careful European botanist, that living algæ grew and flourished at a temperature of 55°–65° C., the record was viewed with suspicion or even contempt. Now we know that the estimate was understated for certain thermal species, and that a temperature of 70°–75° C. is by no means prejudicial for some. The subjoined list represents the genera and species that have been accurately determined, and which can so live and grow in water above the maximum for other plants, viz., 40°–45° C., that they may well be designated "thermophile species" (2, 3, 4).

Chroococcus thermophilus Wood.
Chroococcus varius A. Braun.
Synechocystis aquatilis Sauvageau.
Synechococcus æruginosus Naegeli.
Synechococcus curtus Setchell.
Glæocapsa montana Kützing.
Glæocapsa ? violacea Rabenh.
Glæocapsa thermalis Lemmerm.
Pleurocapsa caldaria Setchell.
Oscillatoria acuminata Gomont.
Oscillatoria sancta Kützing.
Oscillatoria boryana Bory.
Oscillatoria cortiana Menegh.
Oscillatoria geminata Menegh.
Oscillatoria okeni Agardh.
Oscillatoria grunowiana Gomont.
Oscillatoria terebriformis Agardh.
Oscillatoria chalybea Mertens.
Oscillatoria animalis Agardh.
Oscillatoria numidica Gomont.
Spirulina subtilissima Kützing.
Spirulina caldaria Tilden.
Phormidium treleasei Gomont.
Phormidium laminosum Gomont.
Phormidium angustissimum West.
Phormidium purpurascens Gomont.

Lyngbya nigra Agardh.
Lyngbya martensiana Menegh.
Aulosira thermalis West.
Symploca thermalis Gomont.
Inactis hawaiensis De Toni.
Plectonema nostocorum Bornet.
Hapalosiphon laminosus Hansgirg.
Hapalosiphon major Tilden.
Fischerella thermalis Gomont.
Dichothrix montana Tilden.
Dichothrix compacta Born. & Flah.
Dichothrix gypsophila Bornet.
Calothrix thermalis Hansgirg.
Calothrix kuntzei Richter.
Calothrix calida Richter.

In regard to these and other thermophilic organisms mentioned by him, a well-known biologist says: "no one doubts that in all the cases cited above, the individuals living in hot springs have been derived from ancestors which lived in water whose temperature rarely exceeded 40° C. The race has therefore become acclimatized, and the question arises: How has that acclimatization been effected?" The writer confesses to being one who would entirely reject the first statement, and who considers that while acclimatization of organisms is constantly proceeding, in the above group we have a primitive unacclimated series, from which cooler species have descended by acclimatization modification.

We would at once sum up our position by saying that we would regard these 41 species of thermophilic algæ as (1) persisting remnants of what was once a greatly more extended, continuous and abundant hot-water flora; (2) that they now live in waters richly charged with all the chemical ingredients—phosphorus at times excepted—needed for plant nutrition and growth; (3) that they are now forming extensive sinter or travertine deposits of siliceous or calcareous nature exactly like rock beds that can be traced back through the geologic formations to the mid-Archæan or Proterozoic rocks; (4) that the conditions under which they now live are probably—almost certainly—identical with those to which they have been exposed for untold ages; (5) that these conditions, though now restricted to limited areas of the earth (like the Yellowstone, Mammoth Spring, Sonoma and others in N. America, the Carlsbad in Bohemia, the Bormio, Lipari and others in Italy, those of Iceland, the Azores, Himalayas, New Zealand and Japan to mention only some of the best known) were once more prevalent, and during the Archæan epoch probably covered a large area of the earth's surface; (6) that in such warm waters, rich in chemical substances and in electro-chemical activities, we might well look for the first beginnings of life; (7) that these living thermophilic algæ are probably the surviving representatives of such anciently originating types; (8) that they, along with the thermophilic bacteria, suggest stages in the gradual evolution or devolution of elaborating phycocyanin, carotin and chlorophyllin pigments; (9) that the now more abundant species inhabiting cooler habitats, which are also exposed to less stimulating chemico-physical environment, are forms which have become cooled down with gradual cooling of the earth's crust, and with restricted exhibition of volcanic activity.

The above categories we will now shortly take up in succession. The *first* suggests that a more extended and abundant thermal flora once existed. When

we find, as in the case of *Phormidium laminosum*, *Hapalosiphon laminosus*, *Symploca thermalis* and others, that these occur over 3 or 4 continents of the Old and the New World in like situations, this is strong proof alike of a former more extended and abundant distribution as well as of their great antiquity. If such be true of forms that have come down to the present day, it is also strong evidence that, in earlier times when volcanic action was widespread, there would be a greater wealth of species, many of which have been exterminated in such extensive volcanic changes as occurred in the New Zealand hot spring region during a recent decade.

Second, the chemical composition of the waters in which the thermophilic algæ occur is exceptionally rich in dissolved inorganic compounds suited for their growth. Numerous detailed direct and also hypothetical analyses are given in Gooch and Whitfield's tables (5) for the leading western American thermal waters, and of these two of the latter need alone be given here from the Excelsior and the Splendid geysers:

Excelsior Geyser.			Splendid Geyser.		
Constituents.	Grams per Kilo of Water.	Per Cent. of Total Material in Solution.	Constituents.	Grams per Kilo of Water.	Per Cent. of Total Material in Solution.
NH_4Cl	Trace	Trace	NH_4Cl	0.0002	0.01
LiCl	0.0121	0.82	LiCl	0.0140	0.86
KCl	0.0821	4.22	KCl	0.0231	1.41
KBr	Trace	Trace	NaCl	0.4940	30.23
NaCl	0.3948	26.81	Na_2SO_4	0.0281	1.72
Na_2SO_4	0.0259	1.76	$Na_2B_4O_7$	0.0335	2.05
$Na_2B_4O_7$	0.0232	1.58	$NaAsO_2$	0.0025	0.15
$NaAsO_2$	0.0034	0.23	Na_2HPO_4	0.0002	0.01
Na_2HPO_4	Trace	———	Na_2CO_3	0.5286	32.36
Na_2CO_3	0.5739	38.97	$MgCO_3$	0.0018	0.11
$MgCO_3$	0.0077	0.52	$CaCO_3$	0.0075	0.46
$CaCO_3$	0.0055	0.37	$FeCO_3$	0.0001	0.01
$FeCO_3$	0.0037	0.25	Al_2O_3	0.0051	0.31
Al_2O_3	0.0023	0.15	SiO_2	0.2964	18.14
SiO_2	0.2214	15.04	CO_2	0.1989	12.17
CO_2	0.1365	9.28			
H_2S	Trace	Trace		1.6340	100.00
	1.4725	100.00			

We may compare these again with Sandberger's analysis of water from the Great Geyser of Iceland that gave in every 10,000 parts: silica 5.097, sodium carbonate 1.939, ammonium carbonate 0.083, sodium sulphate 1.07, potassium sulphate 0.475, magnesium sulphate 0.042, sodium chloride 2.521, sodium sulphide 0.088, carbon dioxide 0.557. The only element absent in the above analyses, that we now regard as important for plant nutrition is phosphorus. In connection with subsequent details the question might be ventured whether possibly sulphur can take the place of phosphorus in such a group as the Schizophyceæ. But in view of the possible proximity, in such thermal areas, of volcanic apatite rocks that might yield phosphatic compounds, the absence is rather noteworthy.

Third. The formation of siliceous and calcareous sinters and their relation to the Schizophyceous algæ may next be considered. The striking observations of Cohn (6) on the waters of Carlsbad, confirmed and extended by Weed (7) and subsequent workers, show that whether in siliceous or in calcareous thermal waters, definite species of the thermal algæ are so able to act chemically on dissolved constituents that the silica or the lime is precipitated in coarse colloid molecules or granules. These gradually unite with each other to produce agglutinated threads of gelatinous or colloid substance which collectively make up the sinter. "Upon the death of the algæ which have separated this jelly from the spring waters, there is a loss of a large part of its water, and a change to a soft cheesy, but more permanent form. This dehydration is carried still further if the silica be removed from the water and dried, but if allowed to remain in the cold water pools there is a further separation of silica, possibly due to organic acids, formed by the decaying vegetation reacting upon the silica salts of the water ; this hardens the existing structures, in certain cases, and generally covers the pillars with a frost-like coating of silica. In general it may be stated that the large vase and pillar forms found in the algal pools can be produced only by the concurrent life and death of these plants, the outer layers continually growing, the inner dying. This is readily seen to be the cause of the peculiar structure of these forms. The central core is a pillar, sometimes hollow, sometimes solid, consisting of thin superimposed layers of silica, each of which corresponds with a layer of algal jelly, which has become hardened by the death of the plants and the loss of water. The column increases in diameter by the growth of the algæ at the surface, and a simultaneous death and hardening of the inner layer of jelly."

Over areas where the sinter is in process of deposition it is noticed, in the more celebrated geyser regions of the world, that a striking variation in color can usually be traced by the naked eye, and equally in the algæ when closely examined. The former give rise to those delicate but magnificent tints of color that have impressed every visitor to the regions in question; the latter shade from pale *Beggiatoa* forms that merge into elongated thread forms, through yellow to yellow-brown, pink, pinkish-green, purple-green, and—along the cooler margins of deposit—to deep emerald green. Reference will be made below to this color relation.

But no matter what the color species of alga be that precipitates the sinter, this soon loses its color and assumes a dull gray tint for siliceous, or a pure white hue for calcareous deposits. In regard to the after-relation of the algæ to the deposits Weed says: "The desiccation of such areas leaves a deposit of sinter whose surface shows no trace of its origin and of the beautiful forms beneath." This uniform opalescent character of the sinter deserves emphasis in connection with what we will state below as to the possible occurrence of rock masses similar in type and origin.

Fourth. In treating of the fourth question it will readily be accepted, we believe, that considerable though the area of hot spring activity now is, such is a

steadily diminishing amount compared with the areas occupied during more and more remote ages of the past. Weed says regarding the Yellowstone region: "There is perhaps no other district in the world where hydrothermal action is as prominent or as extensive as it is in the Yellowstone Park. In this area of about 3,500 square miles, over 3,600 hot springs and 100 geysers have been visited and their features noted, and there are also almost innumerable steam vents." But there are many geological evidences to prove that back to the time of the Cambrian and the Archæan or Proterozoic epochs such areas were evidently greatly more extended than now. There is no reason therefore to suppose that such simple algæ, carrying on the active rock-forming function that they do, were absent from the waters of such areas as the above, where an abundant food supply existed for them, that might be scant and hard to obtain elsewhere, either in cooler waters, on land, or in the sea. So we may well accept it as highly probable that some of these thermophilic algæ correspond, so to speak, to the Terebratulas and the Lingulas of the animal kingdom, in that they are very probably forms which have lived on through the ages, and through uniform environmental conditions, that represented their primitive environmental surroundings.

With increasing cooling of the earth's mass, derived species may have branched off from them that became modified to less stimulating or to chemically more restricted surroundings, and which would account for the numerous species of Schizophyceæ now living, some in fresh water, some on land, some in saline or in brackish regions, some by the seashore. If we bear in mind also the strongly mineral nature of the geyser waters, we need not wonder that such areas as Salt Lake show extensive beds of blue-green algæ like *Microcystis packardii;* that *Oscillatoria salinarum* can flourish in the escaped liquor from the salt works of Porto Rico, or that *Cœlosphæriopsis halophila* should live in a salt lagoon of the Hawaiian Islands. *Synechococcus curtus* again is said by its discoverer Gardner to have been found "floating in myriads in hot salt water, near Key Route power house, Oakland" (4).

Instead therefore of regarding the thermophilic algæ as acclimated species, there is equally good or even more abundant reason for considering, that they now inhabit surroundings which have remained little if at all altered from the period of their early evolution.

Fifth. Under this caption it might be observed that freshwater limestones, lime silicates and siliceous rocks, which often show few or no traces of organic remains, occur in most of the geological formations back to the Archæan epoch. At times they occur in a pure, at times in a more or less impure state. The thickness of the beds varies greatly from a few inches to many feet. Opinion was long divided as to their origin, but their probable vegetable formation is being more clearly emphasized. Thus speaking of the later Archæan or Proterozoic rocks Geikie (8) says: "these ancient stratified formations do not consist merely of clastic sediments. They include important masses of limestone and dolomite, sometimes highly crystalline, but elsewhere assuming much of the

aspect of ordinary gray compact Palæozoic limestone. Sometimes they contain a considerable amount of graphite, and some of the shales are highly carbonaceous. In other places they are banded with layers and seams or nodules of chert, in a manner closely similar to that in which the Carboniferous Limestone of western Europe contains its siliceous material. Sometimes the chert bands are as much as forty-five feet thick. The general character of these mingled carbonaceous, calcareous and siliceous masses at once reminds the observer of rocks which have undoubtedly been formed by the agency of organic life."

The beds also of opals, opal marbles and other siliceous compounds, also the marls and related carbonate rocks may in part at least have originated from the algæ of hot-spring activity. But even as temporary masses of colloid silicates and carbonates these sinters may often and widely have been deposited, to be again redissolved, or withered for formation of other sedimentary rocks. The evidence therefore seems fairly abundant and suggestive, that between the close of the igneous period, and before the deposition of Cambrian rocks, deposits were forming that can best be explained as due to the activity of plant organisms, and not least of Schizophyceous algæ.

Sixth. In approaching this topic it may be said that, during the past half century, biologists have tried to account for, or to trace the beginnings of life in still oceanic—even abyssmal—deposits or formations; in lagoons bordering the sea where varied inorganic compounds can accumulate to interact on each other; or again they have somewhat vaguely suggested the possibility of hot spring areas as active centers of molecular change. The last seems to the writer the only one that has much to be said in its favor.

We now recognize fully that organic bodies are fundamentally colloid aggregations. In hot springs colloid action and reaction are proceeding more actively and steadily than in any other region of the world. All organic bodies contain at least seven elements, which are either linked together in complex manner as colloid molecules, or they aid by contact action in building up and maintaining such molecules. As already noted, all of these elements except phosphorus exist side by side in loose states of combination and under high electro-chemical tension, in probably all of the hot springs of the world, though in siliceous springs like the Great Geyser, the silica predominates, in carbonate ones like the Mammoth geyser, lime predominates, while in the sulphur-bacterial springs to be treated of below, the element sulphur predominates.

The blue-green algæ and the thermophilic bacteria are formed fundamentally of a colloid pellicle that we may term mucilage-cellulose, and of enclosed protoplasm also of colloid nature, but of highly complex molecular composition. The latter excretes the former as a limiting osmosizing tension layer, much as does the enclosed substance in a Traube cell deposit the pellicle of diverse composition around it. More perfectly and on a larger scale in the post-igneous period of the world's history than at any later time, areas must have existed that closely simulated the hot springs of to-day, and where molecular colloid interactions

must have occurred on a large scale. There and then environmental conditions must have existed, that were eminently favorable for the upbuilding of complex colloidal bodies, and so there and then the remote and probably simpler ancestors of our existing thermophilic algæ may well have originated.

It should further be added that, while extensive areas of hot spring activity probably—almost certainly—existed, the geologist has advanced clearest evidences to show that in the mid or late Archæan epoch, lands of denudation, lagoon expanses, sea cliffs, and ocean areas were then established.

If we attempt with the physicist and geologist to estimate the time-limit that elapsed, say from the mid-Archæan to the close of that epoch, it is generally agreed that the period is a long one. Thus Haeckel, using the data of various geologists, considered that the Archæan and Cambrian rocks together averaged 63,000 ft. in thickness, and required about 52,000,000 of years for their formation, a length of time greater than that proposed by him for all of the later formations up to this date. Geikie has said "The geological evidence indicates an interval of probably not much less than 100,000,000 years, since the earliest forms of life appeared upon the earth, and the oldest stratified rocks began to be laid down."

Even if we limit the period from the mid-Archæan to the beginning of the Cambrian to 20,000,000 of years, the active changes proceeding then, as testified by the structure of the earth's crust, would be most efficient factors in evolving and modifying plant species. So an abundant hot spring flora of primitive type may slowly have originated and become distributed over wide regions during the mid and late Archæan or Proterozoic epoch, and from this may have evolved adaptive types of land, cool lake, lagoon, estuarine and sea dwellers.

This brings us to the consideration of evidence in favor of adaptation and modification of such thermophilic algæ from a warm to a gradually cooler environment. With the exception of thermophilic bacteria, that are discussed later, no other group of plants is capable of passing its entire life cycle at temperatures between 50°–75° C. Yet even at the present day there exist 40 or more such species of wide geographic distribution. A remarkable and unique feature of the Schizophyceæ, however, is that not only the genera, but even many of the species, are capable of flourishing under most diverse environmental conditions. In saying this the writer bears in mind that wrong specific identifications can readily be made in this group, since diagnostic descriptions are limited often to a few characters. But discounting a wide margin of possible error here, the statement just made seems eminently correct.

Thus the genus *Inactis* includes species that grow in freshwater ponds and there form calcareous pebbles, or that coat wet rocks or live in rushing cataracts, that grow in hot water or that cling epiphytically on marine algæ. Species of *Spirulina* may grow in brackish or salt marshes, in hot sulphur springs, on marine algæ, or in pools of fresh water. The single species *S. subtilissima* is recorded from thermal waters of Italy and Africa, from a salt creek in Nebraska, from a

sulphur spring in California, and in washings from marine algæ of Hawaii. Many similar records to these would suggest a plasticity and adaptive capacity at the present day that seem only possible of explanation as due to long continued exposure to altering environment. That so many freshwater and cool species have developed is probably due to geographic isolation and subsequent adaptation to a uniform and stable set of surroundings, in certain originally primitive types.

The writer graphically proved nearly two years ago that certain of them can resist great extremes of temperature, of drying and of insolation. For on a macadamized road leading from Morgarten to Schwyz, he watched, for two weeks, numerous examples of a nostocaceous species that grew from between the broken road metal. These shrank to small semi-leathery flecks when hot summer suns made the stones warmer than the hand could comfortably bear; they rapidly became swollen up when rain fell for an hour or two, while in winter they were exposed on the inclined road to temperatures greatly below that of the freezing point. A temperature range of 70°–75° C. seemed a concomitant of their annual life cycle.

Under the *eighth* heading, it would be impossible in the present paper to discuss at length the question of color variations as shown by the thermophilic algæ, and the possible relation of these to the important question of chlorophyll evolution. Suffice it if we here say, that from the physiological knowledge we now have of yellow, yellow-brown, yellow-red, purple-green, and blue-green schizophyceous pigments, it seems likely that we have here to deal with possibly one, perhaps two series of color compounds, that may all be capable of utilizing the sun's rays in the elaboration of synthetic plant foods.

Weed's graphic description therefore of the color gradations seen in many hot springs deserves quotation. He notes that as the water from a spring "flows along its channel it is rapidly chilled by contact with the air and by evaporation, and is soon cool enough to permit the growth of the more rudimentary forms which live at the highest temperature. These appear first in skeins of delicate white filaments which gradually change to a pale flesh-pink farther down stream. As the water becomes cooler this pink becomes deeper, and a bright orange, and closely adherent fuzzy growth, rarely filamentous, appears at the border of the stream, and finally replaces the first-mentioned forms. This merges into yellowish-green which shades into a rich emerald farther down, this being the common color of freshwater algæ."

The *ninth* line of inquiry has been already sufficiently touched on in the foregoing paragraphs, and need not detain us.

The second great group of the Protophyta is the Schizomycetes or Bacteria. Even more diverse views have been propounded, as to their cytology, than for the blue-green or schizophyceous series. We would regard them as being composed of a mucilage-cellulose or cellulose membrane, which in many of the more motile forms seems to be permeated by nitrogenous compounds. The protoplasm, as in the previous group, is rich, granular, and abundant; sap vacuoles are

small or appear to be absent in active cells; diverse food granules may be seen in the protoplasm; while in regard to a nucleus we would favor the view of most bacteriologists, that such is absent or only represented by minute chromatin granules ("chromidia" of authors) that may be loosely linked together in the substance of the protoplasm.

In studying the environmental relation of the group from the standpoint of protoplasmic adaptability, it may well be said that during the past 10 years few lines of experimental observation have produced so varied and suggestive results as those dealing with the thermophilic bacteria. Their presence in hot springs had been demonstrated almost a quarter century ago, but their existence in unlimited quantity in soils, in fermenting vegetable refuse, in manure, in the cloaca and alimentary canal of vertebrates, as well as on many living exposed plant parts, had not been suspected. As repeated experiment has shown, these thermo-bacteria are nearly all active at an optimum temperature of 55°–65° C., they are sluggishly—though sometimes actively—vegetating at 70°–75° C., while their spores can in most cases retain vitality at much higher temperatures.

But more than ordinary interest attaches, in our present inquiry, to the bacteria that flourish in siliceous, in calcareous, or in sulphur springs. Setchell (9) concluded after study of many western American localities, that "the chlorophylless Schizomycetes (or bacterial forms) endure the highest temperatures observed for living organisms, being abundant at 70°–71° C., and being found in some considerable quantity at 82° C. and at 89° C." He states also that in siliceous waters the limit of life for active bacteria is 89° C., but in calcareous waters the limit is 71° C.

About eight years before publication of Setchell's results, however, Karlinski (10) studied the waters of the hot sulphur springs of Ilidze in Bosnia. In the early part of his paper, he gives a table showing the composition of the water, and which the writer subjoins for comparison with those already given. One of the two springs that yield the supply has a temperature of 58° C., the other of 51° C.

Sulphate of potash	0.344	Bicarbonate of magnesia	4.547
Sulphate of soda	8.191	Bicarbonate of iron	0.077
Sulphate of strontium	0.030	Oxide of alumina	0.012
Borate of soda	0.053	Silica	0.485
Chloride of sodium	0.144	Hydrogen sulphide	0.039
Chloride of calcium	5.100	Free CO_2	4.496
Hyposulphite of calcium	0.019	Lithium, manganese, ammonia	traces
Phosphate of calcium	0.013	Organic substance	0.152
Bicarbonate of calcium	10.666	Insoluble constituents	24.990

He accordingly draws attention to the special abundance of sulphate of soda, of the two chlorides, of bicarbonate of lime, and of free CO_2. But in contrast to those already tabulated in this paper, the writer would emphasize the presence of iron and of phosphorus compounds.

In the Ilidze waters Zalinski found two thermophilic species. One was named *Bacterium ludwigii*, the optimum temperature for which was 55°–57° C.;

it continued to flourish even at 60°–70° C., and ceased growth only at 80° C. It was of a light yellow hue, and so contrasted with a snow-white form *B. ilidzensis capsulatus*, whose optimum was 59°–60° C., which still grew and multiplied at 60°–70° C., but could endure a higher temperature.

Miyoshi (11) found 9 types of bacterial organism in the thermal waters of Yumoto, at 51°–70° C. Of these 5 were red-colored, and 4 were colorless forms. Again Falcioni (12) found three varieties of what he identified as *Bacillus thermophilus* in the hot springs of Bullicame di Viterbo. If his identification is correct, this would be the same organism as Rabinowitsch and others have found in earth, manure, etc. Its optimum temperature was 60° C.

Georgevitsch (13) found in the sulphur springs of Vranje, a variety of the same bacillus which endured a temperature of 70° C. At 49°–50° C. it ceased to grow or multiply; its optimum was 56°–60° C. when spore-formation took place; at 68°–70° C. a reduction of vitality occurred. So for this as for several other thermophilic bacteria the minimum temperature is 48°–50° C., the optimum is about 58° C., and the maximum 70°–75° C. These results again are all similar to those of Benignetti for the hot waters of Acqui in Piedmont, and so it is probable that when world-wide studies have been made of the micro-organisms of sulphur waters a likely agreement of these will be noted, if the bacteria at all correspond to the blue-green algæ.

The literature on the thermophilic bacteria that inhabit soils, manure heaps and even the alimentary tract of animals is already extensive, but is admirably summarized by Ambroz up till a year ago (Central. für Bakt., 48 (1911), 257). These live in an optimum temperature of 55°–65° C., at 35°–40° C. they show minimum dormancy, at 70°–75° C. the maximum is reached. Their widespread abundance over probably the whole world, as Globig's tests would indicate, is one of the biological surprises of recent years, but is perfectly in keeping with the line of argument pursued in this paper.

Considerable diversity of opinion has been expressed as to their origin and biological significance. Below, the writer suggests a possible origin that may connect them equally with other bacteria that live in ordinary temperatures, and with the blue-green algæ. And in this connection the observation of Rabinowitsch (15) that of the eight types studied by her, the color varied from white through gray-yellow to brown, red and gray-green is really important.

Between the thermophilic bacteria and those which live at ordinary temperatures, all gradations have been studied. Thus *Micrococcus prodigiosus* has been proved to have a wide adaptability of temperature range, while Eisenberg's (16) recent experiments with *Bacillus anthracis* prove that it is active alike at normal temperature and up to 70° C.

If we review now the Schizomycetes as a whole, it seems to the writer entirely warrantable to conclude, that the most primitive group is that of the Thiobacteriaceæ or sulphur and iron precipitating species, which are partly thermophilic, and which alike in cell morphology and in formation of mineral deposits

are almost identical with many of the thermophilic Schizophyceæ. These again show every type of gradation in cell structure and in life cycle to the genera of the Leptothriceæ that are mainly saprophytic or parasitic. They again lead by *Streptothrix, Mycobacterium* and others to genera of the Spirilleæ on the one hand, and to the larger forms of *Bacillus* and *Bacterium* on the other. Whether the group of the Coccaceæ should be viewed as a direct offshoot from simple spherical Schizophyceæ, or as condensed and rounded derivatives from *Bacterium* is a question that need not concern us at present. The important announcement just made by Drew (17) "relates to the rôle of certain bacteria in depriving surface sea water of nitrogen and in precipitating the vast deposits of chalky mud (oolite) of the Florida-Bahama region." This is but another proof of the geologic activity of the Schizomycetes, though it is of immense value as carrying such activity into the ocean, and of possibly explaining to us the origin of the great marine chalk and lime beds of former epochs.

It is regrettable that our knowledge is still very limited as to the bacteria of siliceous and calcareous springs. But accepting their recognized occurrence there, and the great abundance of sulphur bacteria in hot sulphur springs, the conclusion seems fully warranted that hot-spring schizophytic organisms—alike in their schizophyceous and schizomycetous sections—were the primitive organisms of the world, and that amid all the environmental changes of denudation, upheaval, cooling, and more recent sharp action of such often severe environmental agents as hot suns, hot and cold winds, ice action, etc., some species have survived practically unaltered, from very ancient time amid primitive thermal waters, while hundreds of species derived from these have adapted themselves to a wide range of environmental habitat.

Naturally, we would regard the algoid or schizophyceous series as the primitive and main stock, since they are chemically autotrophic. The saprophytic and parasitic derivatives are in all likelihood offshoots from these. But it must here be borne in mind that though Winogradsky's and Molisch's views differ somewhat as to details of nutrition of the sulphur bacteria, these plants may indicate a capacity for autotrophic nutrition, or at least for chemical elaboration and energy-storage, that might give them a synthesizing dignity and independence apart from the Schizophyceæ.

For the Schizomycetes then, as for the Schizophyceæ, it is true that many species have become adapted to cool surroundings, and can even continue to grow and multiply at or below the freezing point. But it is as true for their spores as for the seeds of flowering plants, that after continued exposure to temperatures of $-70°$ C. to $-100°$ C. many still survive. So direct experimental and observational evidence both lead us to believe that rich and dense plant protoplasm had from earliest time an adaptive capacity up to at least 100° C., and also that it had or in time acquired a life-adaptation to $-100°$ C. or less. Such a wide range of temperature adaptability would aid many species to survive that otherwise would have succumbed.

One is tempted now to inquire as to the action of environmental light rays on both of the schizophytic groups. Unfortunately our knowledge is still so limited, that we can only speak with reasonable certainty along one line. Several sets of experiments, from those of Ward onward, demonstrate that when light passes a definite maximum of intensity it becomes injurious and even actively destructive. Thus in *Microbiology* (18) we read "most bacteria are killed by direct sunlight in a few hours," and "the different colors of the spectrum do not act alike; the part of the spectrum from red to green is practically without influence upon microorganisms, while the blue light acts strongest, and the intensity decreases in the violet and ultra-violet." This is exactly true of the higher nucleate plants, as first pointed out by the writer (19).

In proceeding now from the Protophyta or non-nucleate to the Metaphyta or nucleate plants, a noteworthy feature is that the cell or several cells that make up each mature organism, tend to become greatly vacuolated by absorption of relatively large supplies of water, while the chromatin that was absent, or present in a more or less "amphiplasmic" state becomes definitely aggregated into nuclear and nucleolar constituents. Possibly one, perhaps both of these changes may limit adaptability to diverse environmental conditions, and not least diverse temperatures, though the writer would lay greatest stress on water content. But when most metaphytic cells—the egg and sperm mainly excepted—become richly protoplasmic, or are protected by mucilaginous or pigmented cellulose or lignin coats, or pass by definite cyclic relation into a dormant resting state where the stored food and the granular protoplasm are relatively great in amount, and the nuclear chromatin is relatively small and surrounded by the former, a like wide range of protoplasmic adaptability to environment is witnessed.

Though greatly more extended and minute experiment and observation are needed, enough results have been secured to guide us. These we will treat of, in gradually ascending series, beginning with the algæ and fungi.

Alike because growing algoid cells are usually much vacuolated, and the resting spores have been little experimented with, our information as to algæ is still scant.

According to the temperature records given by West (20) for the material collected by A. W. Hill at hot springs in Iceland, not only blue-green algæ but numerous species of diatom, three species of the Desmid *Cosmarium* and even a species of *Zygnema* live at temperatures of 49° to 61° C., thus apparently confirming Berggren's and Börgesen's accounts for New Zealand and Iceland. A more careful study of such higher algæ in relation to environment is greatly to be desired however. But amongst fungi we know that yeasts such as *S. cerevisiæ* and *S. hansenii* can live after several days' exposure to −70°–100° C., though vegetative activity starts about 10° C. From the latter temperature upward, yeast continues to bud in nutritive solution, according to A. Meyer, up to 53° C., while air dried yeast remains alive up to 100° or 110° C. The *duration* of life, at optimum temperature, of pressed yeast is stated by Claude Bernard and Schumacher to continue for two years.

Pasteur found that the dry conidiospores of *Penicillium glaucum* could endure a temperature of 108° C., but that in liquid they were killed at 100° C. The dry spores of species of Smut (*Ustilago*) survive heating to 104°–120° C., but when moist are killed at a temperature of 60°–73° C. Chodat (20) exposed spores of *Mucor mucedo* to a temperature of −70° to −110° C., and even considered that the mycelium may be equally frozen. He concludes that "la vie est conditionnée par certaines structures. Les forces qui les mettent en jeu peuvent etre des forces toutes physiques. Elles sont simplement les sources d'énergie qui pourront mettre la machine en mouvement."

But the behavior of many lichens in the vegetative state is highly instructive, compounded as they are of a fungoid and of a schizophyceous algal constituent. Growing on bare open rocks, they may be exposed for a few hours or days to rain, and then for weeks or months mayhap to broiling suns. Along the French Riviera coast in July the writer has placed his hand alongside some of these as they grew on the red rock, and had speedily to withdraw it again as a matter of comfort. Kerner (22) says regarding them: "The crustaceous lichens adhering to the limestone rocks of the wild regions of the Karst of Istria and Dalmatia (*Aspicilia calcarea, Verrucaria purpurascens*, and *V. calciseda*) are regularly exposed on cloudless summer days to a temperature of 58° to 60° without injury, and the edible lichen (*Lecanora esculenta*), is often heated in the deserts, along with the stone on which it grows, to fully 70°, and yet is not destroyed."

Few exact records have been published for the mosses, and a promising field for inquiry is here open. But the recent studies of Irmischer (31) suggest future extended observations that will yield important results.

While ferns are as a group umbrophilic plants, it can equally truly be said that species of *Pellæa—e. g., P. atropurpurea—Notholæna*, and some epiphytic tropical species of *Polypodium* are truly thermophilic. The leaves of such species are often smooth and leathery; they contain a relatively small amount of moisture even after rain; they grow on exposed gray-white rock faces, or epiphytically on dry tree trunks; they may remain shrivelled and apparently dead for weeks or even months without moisture other than dew; at times even hot dry winds accentuate the often intense insolation. Yet they live unharmed at temperatures which may run from 65°–70° C.

On the hot white sandy knolls over the savannahs near Wilmington, N. C., *Selaginella acanthonota* has its hard wiry patches of branches exposed for weeks to direct day temperatures of 60°–65° C., while its near ally the well-known resurrection plant of California and Mexico (*Selaginella lepidophylla*) can not only endure such heats, but will live for months out of the ground in a box, and if again planted will unfold its shoots, revive and grow.

In all of the above sun-exposed plants, it is evident that—no matter what view we may hold as to the function of cuticle and epidermis in relation to subjacent cells—the epidermal cells at least were exposed to all of the constituent rays of an intense light.

If attention be now turned to the spermatophytes or flowering plants, evidence that has accumulated during the past quarter century entirely favors the view, that many plants or plant parts are adapted to much more diverse environmental relations than we formerly inclined to grant. Since the successful endurance by seeds of diverse environmental changes is an important feature in the perpetuation of species, we may begin our study with them.

Quoting from the passage already referred to from Kerner he says: "Seeds which are deposited on the desert sands, and survive in this position long periods of drought, do certainly assume the temperature of their environment, and although at noon this often amounts to 60°–70°, it does not injure these seeds: since when the rainy season returns, they are roused from their summer sleep and germinate in the cool and moistened soil. The highest temperature in the superficial layer of soil has been observed near the equator at Chinchoxo on the Loango coast. Here, in many cases it exceeds 75°, often attains 80°, and once attained to even 84.6°. Nor is this soil destitute of annuals during the rainy season, and without doubt the dry seeds of these plants have been lying for months in the sand, sometimes heated to over 80°, without losing their germinating power."

Of various seeds also which had been deprived of a safe amount of water, he states that they can be heated for 3 hours to 100° C., and yet the greater number may germinate. We can scarcely doubt that every living cell in the seeds was as fully exposed to a temperature of at least 70°–75° C. as were the schizophyceous algæ of the hot springs. Even more remarkable were the results secured by Brown and Escombe (23), also by Thiselton Dyer (24) as to protoplasmic adaptability of seeds to extremely low temperatures. The former experimenters selected 12 kinds of seed taken from eight different families, some of which were albuminous, and some exalbuminous. The seeds were air-dried and so contained about 10 to 12 per cent. of natural moisture. After being slowly cooled they were immersed in a flask of liquid air, and exposed to a temperature of −183° to −192° C. for 110 hours. But on removal they showed as good germinating capacity as did control seeds.

In Dyer's experiments six kinds of seeds from five families were used, and their germinating capacity was tested by sets of control seeds. Some were exposed in liquid hydrogen to a temperature of −250° C. for an hour; others were similarly exposed for six hours, while a third set was exposed to liquid air. All germinated as perfectly as would any good seed sample, and as did the control seeds. Such experiments not only confirmed the earlier results secured by C. de Candolle and Pictet, they strengthened Pictet's conclusion (25) that "since all chemical action is annihilated at −100° C., life must be a manifestation of natural laws of the same type as gravitation."

De Candolle's (26) added experiment of placing seeds in the snow-box of a refrigerating machine at −37° to −53° C., for 118 days leads us to note the extreme vitality of some seeds. We now have sufficient verified proof to accept it that

some malvaceous and particularly some leguminous seeds, remain in a state of "dormant vitality" for a period of 5 to 50 years at least. That they are living and not dead bodies during all of this period, is shown by their being germinable at any time; by their undergoing a slow but gradual loss in germinating capacity; and that a stage is ultimately reached when life-changes can no longer be started; that is, the irritability of the cells in the albumen and in the embryo, which may have persisted for many years, fails longer to express itself.

Waller (27) in his electrical blaze-response experiments failed to obtain any evidence of life in such dormant seeds, and felt that he was accordingly placed in a dilemma. He in part tried to escape from it by saying that "it is possible—or rather, certain—firstly that our means of chemical investigation are not refined enough to reveal to us the smallest and most infinitesimal changes that may be going on in an apparently dry and perfectly dormant seed; and second it is possible that chemical change may be completely and absolutely arrested (*e. g.*, by low temperature) without that arrest being of necessity final and definite."

Without at present going further into the subject, we would merely state the fact that under definite environmental states some seeds contain cell protoplasm—probably mainly in the embryo—that retains its irritable and chemico-physiological capacity for response through a period of at least half a century, though in a so greatly reduced state of activity that galvanometric records seem to be feeble or unobtainable.

Before leaving this subject, reference may be made to the peculiar results obtained by Romanes (28) with seeds that were exposed in highly exhausted vacuum tubes for 15 months; or for three months, and thereafter transferred to tubes charged at air pressure with gases or vapors of hydrogen, carbon monoxide, carbon disulphide, ether, etc., for an added period of twelve months. His result was "that neither a vacuum of $\frac{1}{1,000,000}$ of an atmosphere, nor the atmosphere of any of the gases and vapors named in the above list, exercised much, if any, effect on the germinating power of any of these seeds." Dyer in the article already quoted states on the authority of another without giving any evidence, that "an injurious effect is ultimately produced." But even granting such, to have secured germination is proof that protoplasm may behave with great endurance to environmental agents.

In view of statements that have usually been current in the past, as to protoplasmic adaptability and resistance, it might scarcely seem likely that the cells of any vegetative part of a flowering plant could endure a temperature higher than 42°–45° C. And while this may be true for each plant in some one or other of its tissues, if we can show that certain living tissues can be exposed to 60°–70° C., and to direct insolation that roughly corresponds in intensity to this temperature record, or again to temperatures as low as −60° C. for hours of each day, then we have gained a clearer insight into the adaptive capacity of cell protoplasm, seeing that all the cells of any flowering plant are derived from the fertilized egg-cell.

Over the hot desertic expanses of the Chihuahuan area in N. America, the Sahara and the Karroo of Africa, or the interior plains of Australia, groups of plants belonging to quite distinct families grow, and sometimes even attain to great stature, under temperature and light conditions that might seem impossible. Thus the yucca, the agave, the cactoid and the xerophitic leguminous groups of the Chihuahuan areas; the grape-vines, the geranioids, the stapelias and the aloes of Africa; the proteads, eucalyptoids, the verticordias and other Myrtaceæ, also the Leguminosæ of Australia are exposed in their leaves or in their shortened stems to an intensity of temperature that must often register 60° to 65° C., and which must be fully felt in the epidermal cells at least of the more succulent types, and throughout the tissues generally in the many dry leathery ones of these regions.

The behavior of the Californian plant *Lewisia rediviva* alone is instructive. In the *Botanical Magazine* it is said that the specimen there figured from Kew was "one of many which, when gathered with a view of being preserved for the herbarium, in British Columbia, by Dr. Lyall, R. N., of the Boundary Expedition, was immersed in boiling water, on account of its well-known tenacity of life. More than one and a half years after, it, notwithstanding, showed symptoms of vitality, and produced its flowers in great perfection in May of the present year, in the Royal Gardens of Kew."

Kerner (22a) and Schimper (29) have both cited cases where, over extensive areas the heat, the cold, and the light influence must all be pronounced. The former cites Chinchoxo on the Loango coast where the soil layer may be 75°–85° C., and Yakutsk in Siberia where − 62° and − 63.2° C. (the lowest temperature hitherto generally observed on the earth) were noticed. There for months the temperature in the shade does not rise above − 30°, but numerous herbs and shrubs are found whose upper organs are exposed for weeks to a degree of cold at which mercury freezes."

But it must equally be emphasized that many plant species have a definite physiological minimum and maximum, during the vegetative period, that may lie between comparatively narrow limits of temperature. Thus the writer (30) has shown not only that related species of *Crocosma* may live or die as they are exposed to slightly different degrees of cold, but that the hybrid between these may show a fairly exact mean between the two. He has also stated that a like condition holds for *Philesia, Lapageria* and their hybrid. Even the units of heat needed to bring hybrids into bloom seem to be—from the writer's studies that have been extended by others since—fairly intermediate in amount between those needed for the parents, if these bloom at different dates.

In summary it might be said that if plant protoplasm shows an adaptability even in spore cells and seeds from 85° C. to 100° C. over long periods, and also to temperatures from − 100° to − 250° C., those cases where it shows a less degree of adaptability probably represent an acquired condition, in which, owing to absorption of extra water by the protoplasm, it is thereby rendered more un-

stable. Setchell well remarks in the paper already quoted: "We find that when a proteid, like egg albumen, is free from water, it does not coagulate at the very highest temperatures which leave it unburned, and that the less the content of water, the higher the temperature of coagulation." The most resistant plant parts are undoubtedly those in which abundant protoplasm, with or without stored protein or other food stuffs, fairly well fills the cell. Such cells or cell aggregations show a wide range of biological possibilities in relation to environment.

The views set forth above may be summarized as follows:

1. Plant protoplasm may show a degree of temperature adaptability that may range at least from − 200° C to + 100° C.

2. The most ancient, and in structure most primitive plants are probably the Schizophyceæ (Cyanophyceæ), which may have originated during the Mid Archæan or Proterozoic epoch, and were probably active agents then, as now, in forming the siliceous and calcareous beds encountered in the strata of that period.

3. The representatives of that group now living in hot springs and thermal waters, seem to be direct or little altered derivative species from the ancient or Archæan types, and no good reasons can be advanced for viewing them as adaptive or acclimated from more cool and temperate species.

4. They, like all thermo-resistant plant structures, have a rich and relatively dense protoplasm, or a stored mass of reserve material with it in the cells, that contribute to their thermo-resistant qualities.

5. The above qualities are aided when mucilaginous walls or cell contents, or thick and pigmented cellulose or ligin or cuticularized walls, exist in the above group, or in any division of the higher plants, since these act as insulators and equilibrators against over-rapid environmental action.

6. That the thermophilic bacteria also represent an ancient series, either derived from the Schizophyceæ by disappearance of the synthesizing cell pigments, or arising independently by utilization of energy from sulphur or siliceous compounds. These like the Schizophyceæ have been active in the formation of extensive rock masses of a sulphurous or ferruginous kind.

7. That from the almost assuredly verified deposit of extensive siliceous, calcareous, sulphur and iron rocks by one of the above two groups in late Archæan times and on to the present day, we have strong suggestion that the Schizophyceæ and Schizomycetes represent primeval groups whose rock-forming activities have been and are shown, where surroundings are favorable.

8. That all physico-chemical, geological and biological knowledge point to the conclusion that thermal spring action was once greatly more extended than now, but that the restricted areas which now show it do not seem to differ in their relations, their deposits, and probably in their organisms, from those of ancient geologic origin.

9. That the molecular composition, chemical activities, high energizing

temperatures, and abundant colloid substances, evidently existent in primitive thermal waters, all favored formation of abundant colloid compounds from simpler constituents, and this on the principle probably of Traube's cells.

10. That the living Schizophyceæ and Schizomycetes show graded advance in cell morphology from simple spherical unicellular and asexual organisms devoid of any recognizable chromatin or nucleus, to thread forms in which chromatin granules or loops are aggregating into a nuclear structure.

11. That protoplasm, as claimed by Pictet, Loeb, and Chodat is a chemical compound "that conforms to the same fundamental laws as do inorganic bodies," but which exhibits a greatly more complex structure and capacity of adaptation and response to environal stimuli, owing to the greatly more complex combination of the organizing molecules.

12. That the Schizophyceæ of thermal springs show varying degrees of coloration of their cells, which suggest graded stages in chlorophyll evolution.

13. That the Schizomycetes originated as a later offshoot from the Schizophyceæ, or as a primitively independent colorless group that utilized chemical energy from siliceous, calcareous, sulphur or other compounds. From this group saprophytic and parasitic forms arose, that developed corresponding habits.

14. That during gradual cooling of the earth, and restriction of volcanic and hot spring activities, thermophilic organisms became adapted to more temperate surroundings, and gave rise by adaptive modification to more recent plants.

15. That throughout the entire vegetable kingdom, at some stage in the life history of many plants, a wide ancestral adaptive capacity is shown by the cell protoplasm to temperature, light and chemical agents.

16. That not merely spores and seeds, but many other parts—even entire plants—of the Spermatophyta, show a wide range of environal relation, that is in no way different from that shown by the simple thermophilic organisms.

17. That relative water content is probably the main determining agent in conferring varying degrees of response on all plants or plant parts, though this is probably correlated with the presence of varying coagulable proteids.

18. That possibly the relation of the chromatin in the Metaphyta, to the protoplasm and to water content, have also an important bearing on species adaptability.

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Tetraplasy, the Law of the Four Inseparable Factors of Evolution

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PHILADELPHIA
1912

PREFACE.

During the last three years the author has made three preliminary statements of the law which is elaborated in this contribution. It belongs to an extended treatise which the author has had in preparation since 1905. It is regrettably incomplete in failing to give concrete examples from nature and from experiment of each of the series of subordinate principles set forth. It seemed best, however, to publish the central principle, or Law of the Inseparable Factors, in its present form rather than to delay longer for time and opportunity to publish the concrete examples.

The author takes advantage of the present opportunity to cite from his purely biological contributions,[1] begun in 1889 and continued to 1912, which form a progressive and more or less connected or consistent interpretation of the evolution phenomena as observed by a palæontologist.

[1] See full bibliography on page 307.

TETRAPLASY, THE LAW OF THE FOUR INSEPARABLE FACTORS OF EVOLUTION.

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Causation or Causality (Lat. *causa*, derived perhaps from the root *cav-* as in *caveo*, and meaning something taken care of; corresponding to Gr. αἰτία), a philosophical term for the operation of causes and for the mental conception of cause as operative throughout the universe. The word "cause" is correlative to "effect." Thus when one thing *B* is regarded as taking place in consequence of the action of another thing *A*, then *A* is said to be the cause of *B*, and *B* the effect of *A*. . . . The senses can say only that in all observed cases *B* has followed *A*, and this does not establish necessary connection. . . . J. S. Mill argues that, scientifically, the cause of anything is the total assemblage of the conditions that precede its appearance, and that we have no right to give the name of cause to one of them exclusively of the others. . . . (3) *Efficient cause* (ἀρχὴ τῆς κινήσεως), the alcohol which makes a man drunk, the pistol-bullet which kills. This is the cause as generally understood in modern usage. . . . *Vera causa* is a term used by Newton in his *Principia*, where he says, "No more causes of natural things are to be admitted than such as are both true and sufficient to explain the phenomena of those things"; *veræ causæ* must be such as we have good inductive grounds to believe do exist in nature, and do perform a part in phenomena analogous to those we would render an account of. (11th Edition Encyclopædia Britannica, pp. 557–558.)

Cause and effect are not two but one. That they are inseparable is indeed recognized by the relativity of the very terms themselves . . . in *content* they are absolutely identical. It is only in *form* that they can be distinguished, and then we may speak of the one as determining, and of the other as determined. (Welton, Manual of Logic, vol. II, p. 25.)

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INTRODUCTION.

How the Problem is Approached.

The total assemblage of the conditions that precede the appearance of "characters" in living animals is the subject of this contribution. To continue the paraphrase of John Stuart Mill's argument, we have no right to give the name of *cause* to one of these conditions exclusive of the others. Mill's doctrine that the *cause* is the "sum total of the conditions, positive and negative, taken together, the whole of the contingencies of every description, which being realized, the consequent invariably follows," is the doctrine on which the Law of the Four Inseparable causes or Factors of Evolution is founded.

Out of the analysis of all the series of conditions which accompany evolution it appears that these phenomena fall into four groups which center respectively around the conditions that we term Environment, Ontogeny, Heredity, and Selection.

In the causes and effects resident in these complexes of conditions are to be discovered the *origins of new characters* and the *transformations of existing characters*.

This contribution to biology is associated with the name of Joseph Leidy, one of the most distinguished members of this Academy, through the fact that he was one of the first to make known the extinct family of perissodactyl quadrupeds now popularly termed the Titanotheres. In attempting to monograph this family from very abundant materials, the author of the present memoir found that these materials presented a rare opportunity of contributing what appear to be new data on the two chief phenomena of evolution above mentioned, namely: the origins of new characters, the transformations of existing characters.

To understand these origins and transformations the author was led to the above-mentioned analysis of all the evolutionary phenomena and conditions.[1] This analysis resulted in the conclusion that all these phenomena are comprised, as indicated above, under four relations or complexes of causes and effects. These relations are external and internal as follows:

External: Environment = the sum of all external conditions.
Internal: Ontogeny = the sum of all conditions of individual, bodily, or somatic development.
Internal: Heredity = the sum of all germinal or blastic forces and conditions.
External: Selection = the sum of all competitive relations between individuals in the struggle for existence.

The true conception of individual animals or plants, of varieties, of species, is that they are all complexes of the relations of these four sets of conditions, which for the sake of simplicity may be called *Factors*, although the word factor does not exactly express our meaning. A factor is defined as "one of several circumstances, elements, or influences which tend to the production of a given

[1] Osborn, H. F., The Ideas and Terms of Modern Philosophical Anatomy, *Science*, N. S., vol. XXI, No. 547, June 23, 1905, pp. 959–961. *Jour. of Philosophy, Psychology and Scientific Methods*, vol. II, No. 17, Aug. 17, 1905, pp. 455–458 (condensed).

result." Thus, for example, it is claimed that "light is the most powerful factor amongst all the agents which influence life upon the earth." Thus Wallace in 1889 wrote: "The importance of natural selection as the one invariable and ever-present *factor* [italics our own] in all organic change and that which alone has produced the temporary fixity combined with a secular modification of species."

There is a perpetual balance between these four factors or complexes of conditions, comparable to the balance of living nature as a whole, such that any disturbance of any one factor produces a disturbance in all the other factors. This recalls to our memory one of Herbert Spencer's definitions of life, namely, that life is a continuous adjustment of all internal relations to all external relations.

This coincides also with John Stuart Mill's doctrine of cause cited above as the "sum total of the conditions, positive and negative, taken together." This conception of a multiplicity of conditions antecedent and consequent must be in the mind of every biologist who seeks to determine the causes of the *origins* and of the *transformations* of characters.

This conception of inseparable relations has more than a theoretical, it has a highly practical bearing in palæontology and in experimental zoology.

Granted that new characters as well as transformations of existing characters must have origins or beginnings, in what part of the complexes of conditions do they first appear? What is invariably antecedent, and what is invariably consequent? Where is the initiation of the chain of conditions which leads to the *genesis* of new characters? This is the question which the author set to himself in the examination of every new character and of every transformation of character discovered among the fossil titanotheres. Was there evidence of a disturbance in the balance of conditions and where did this disturbance originate?

This method of analysis by which the answer shall be attained appears to be the right one, but the answer itself is not yet. The first step is the recognition of the universal law of the inseparable actions and reactions of the four factors, a law which we propose to designate as *Tetraplasy*, from τέτρᾶ (four) and πλάσσω (to form, mould, shape).

After several years of reflection and analysis of the evolution of the titanotheres, the author first presented this law in an address before the Department of Zoology at Columbia University November 3, 1905. It was not published,[1] however, until after the Boston meeting of the Seventh International Zoological Congress of August, 1907. In December, 1908, the subject was presented before

[1] Osborn, H. F.: Evolution as it Appears to the Paleontologist. Address before the Seventh International Zoological Congress, Section of Palæozoology, Boston, Aug., 1907. *Science*, N. S., vol. XXVI, No. 674, Nov. 29, 1907, pp. 744–749. *Proc. Seventh International Zool. Congr.*, Boston Meeting, Aug. 19–24, 1907, Cambridge, Mass., 1912, pp. 733–739. The Four Inseparable Factors of Evolution. Theory of their Distinct and Combined Action in the Transformation of the Titanotheres, an Extinct Family of Hoofed Animals in the Order Perissodactyla. *Science*, N. S., vol. XXVII, No. 682, Jan. 24, 1908, pp. 148–150. Biological Conclusions Drawn from the Study of the Titanotheres, *Science*, N. S., vol. XXXIII, No. 856, May 26, 1911, pp. 825–828.

the American Society of Zoologists at the New Haven meeting and published a few weeks later under the title *The Four Inseparable Factors of Evolution, Theory of their Distinct and Combined Action in the Transformation of the Titanotheres, an Extinct Family of Hoofed Animals in the Order Perissodactyla.*

Reasons for the Historical Method of Analysis.

The reason perhaps that this law is connected with the study of an extinct group of animals is that the hypothesis of the simultaneous operation of several factors on different groups of characters could only suggest itself to a palæontologist working upon a very complex organism, in which an almost countless number of characters are simultaneously evolving.

A gross representation of what is observed as to "characters" in the study of a number of different organisms through successive phyletic stages is seen in the following scheme.

Progressive Steps.	Characters.	Progressive Steps.
	A	1 2 3 4 +
	B	1 2
3 2 1	*C*	
	D	1 2 3
4 3 2 1	*E*	
5 4 3 2 1	*F*	
	G	1 2
	H	1 2 3 4 5
1	*I*	
3 2 1	*J*	
	K	1 2 3
	L	1 2 3 4
1	*M*	

This representation is gross because (1) the progressive and retrogressive steps instead of being sharply defined, as indicated by numerals 1, 2, 3, 4, and so on, are delicately intergraded; (2) the number of characters is very much larger than indicated above. It is estimated that there are at least 560 independent "characters" evolving simultaneously in the grinding teeth alone.

The palæontologist is in a peculiarly favorable position to observe both the origins of new characters and the transformations of existing characters as *visible modes of evolution:* the palæontologist enjoys the unique advantage denied to all other zoologists of being present before the birth, at the birth, during the progress, into the rise, decline and death of new characters and organs.

The genesis of single characters is apparently a simple, concrete problem. When and how does a new cusp arise on a grinding tooth? When and how does a new horn arise on a skull? When and how does a broad skull change into a long skull, and *vice versa?*

In seeking, however, to explain the conditions or causes which give rise to these things it is necessary for the palæontologist to remind himself constantly of the following important distinction:

New hereditary characters appear in the body.
New hereditary characters reside in the germ.

The palæontologist is only observing *appearances*. From the laws governing these appearances he must deduce what is going on in the germ. It is necessary for him, therefore, to secure a broad biological foundation for his observation and reasoning and to see how far the phenomena which he observes, or thinks he observes, square with the phenomena observed by special students of ontogeny, selection, and heredity. The body may be distinguished as the *soma* and the germ as the *blastos*. To designate new characters which apparently make their first appearance in the soma we may use Weismann's term *somatogenic;* to designate those which so far as we can perceive make their first appearance from the germ we similarly use Weismann's term *blastogenic*.

This distinction corresponds with the two great and more or less contemporaneous movements in living things.

The first movement (ontogeny), which has been known and observed from very ancient times, is that of the developing organism, its growing and functioning body or *soma;* this movement is called ontogenesis, or individual genesis. These are the visible expressions of the forces, potentialities, predispositions and reactions to environment derived from the germ, or heredity-substance.

The second movement (heredity), which has been realized as entirely distinct only in modern times, is in the forces, potentialities, and predispositions of the germ, or *blastos*.

Thus the two kinds of movement and genesis of single characters in all living things may be clearly distinguished as

Blastogenesis,	-genic,
Somatogenesis,	-genic.

The soma (ontogeny) is relatively visible and measurable. It enjoys contact and combat with all the forces of nature, consequently some new characters may arise in the soma. It is also the carrier or vehicle of the blastos, it is the environment of the blastos, or intermediary between the outer environment and the blastos. The forces of the blastos are invisible; in the mammals they are remotely buried and removed from environment; the blastos (heredity) carries along all characters from generation to generation; it modifies characters; it loses characters; it gains characters. Whereas certain new characters which arise in the soma are merely transient and may not appear in the blastos, we have reason to believe that all new characters which arise in the blastos appear in the soma. Quite marvelous and inconceivable to us is the manner in which the infinitesimally minute blastos can carry the infinitely grand and diverse characters of the soma of such animals, for example, as *Balænoptera, Elephas, Homo*.

Still more marvelous and inconceivable is the evolution of the blastos, its incessant change, its gain and loss of characters, always and continuously in the main current of adaptation, or of fitting the soma to its activities and its environ-

ment, although there may be a dysteleology of side currents, of lagging characters in which the blastos does not, so to speak, keep pace with the soma, as well as of neutral characters which do not appear to be adaptive. This mutability, or evolution movement, or whatever it is that is in progress in the blastos is the chief and most difficult matter either to explain or to form any conception of.

Emphasis may be laid on the words *adaptive need or necessity* because there is distinct evidence in palæontology that the blastos is not evolving alone through its internal forces independently of the external forces of ontogeny and of environment, but that there is some harmony or form of interaction, the nature of which we do not understand.

The *appearances* which the palæontologist observes in the origins of character and the transformations of character are simply *modes of evolution*. It is, however, from the analysis of these *modes of evolution* as well as by experiment that we must ultimately discover the causes or factors, if, indeed, they are discoverable. These modes of evolution present themselves under such widely different aspects to different classes of observers that we are reminded of the fable of the elephant and the nine blind men, who formed nine entirely different opinions as to the nature of the animal through judging wholly by the respective parts with which the hands of each happened to come in contact. The stout opinions of these nine blind men have their more or less clear counterparts in modern biological investigators, who are in reality studying different aspects merely of the same great phenomena. There is first the standpoint of the natural philosopher of the Herbert Spencer type; then that of the systematic zoologist and field naturalist or botanist; of the breeder, horticulturalist, and fancier, typified by Mendel, De Vries, and Bateson, working in an entirely different field of facts; of the anthropologists and anatomists who deal again with a distinct class of phenomena; akin to this is the work of the student of animal mechanics. Then there are the observers of geographical distribution and segregation, such as Gulick and Ortman. In the opposite extreme the observers of cell structure, such as Nägeli, Boveri, and Wilson are in a circumscribed field of their own. The experimentalist is on the borderland between the field naturalist, the student of cell structure, and the student of animal mechanics. The biological statistician has his own field of observation. The palæontologists have divided into two groups, those who have directly observed the origin and transformation of character, like Waagen and Hyatt, and those who have entered into mechanical explanations, like Cope. The subjective and objective elements in observation and induction may be expressed thus:

Differences in the knowledge, personality, and philosophical equation of the observer	×	Differences in the kinds of objects observed	×	Differences in the apparent modes of change in each of these objects	=	Resultant inductions and conclusions.

It is a familiar psychic process that predisposition for a certain theory causes corresponding aberration of vision; facts which agree with one's theory are seen

and collected more readily than those which do not. A certain observer, for example Cope, starts with a predisposition for the theory of the transmission of acquired characters, we will say. His studies are confined to anatomy, animal mechanics, and palæontology; he does not at first concern himself about heredity; he arrives perhaps at an erroneous conception of the factors of evolution. The fallacy of Lamarck, Spencer, Cope, and all other Lamarckians, if it be a fallacy, is the time-honored *post hoc ergo propter hoc.* The failure of some ultra-Darwinians has been the equally ancient one of the "undistributed middle" or *ab uno disce omnes: e. g.*, there are modes of evolution, selection explains some modes of evolution; all modes of evolution are explained by selection.

Or the observer, for example, De Vries, is a master of botany and of the experimental method, well grounded in heredity, cytology, and in experimentalism. He has not perhaps looked sufficiently into the facts of anatomy and palæontology; he arrives perhaps at a too comprehensive application of the particular modes of change which he observes.

From these illustrations we realize that the changes which the different classes of observers see going on are simply the *modes of evolution;* the underlying causes of these changes can, in our opinion, only be discovered through a synthesis of the phenomena as observed by all the various classes of observers. It is obvious that any general theory of the causes of evolution must not be inconsistent with any of the well attested modes of evolution. We must keep clearly in mind that we have accumulated a vast amount of exact knowledge about the modes of evolution and comparatively little about the sequence of causes and effects.

The discordance of opinion so conspicuous today, which is entirely due, as we believe, to the diversity of the gateways through which the phenomena have been approached, is paralleled by the apparent but not real discordance in the history of successive theories.

The chief gateways or materials of observation have been the predisposing sources of these successive "evolution theories." There are only four of these gateways, namely, environment, ontogeny, selection, and heredity. The first explorers, Buffon and Treviranus entered through environment. Lamarck, Spencer, and Cope entered chiefly through ontogeny, Darwin and Wallace entered chiefly through selection. Similarly Weismann and Bateson, entering through the gateway of heredity reach an equally exclusive standpoint.

Paradoxical as it may appear these observers are at once right and wrong. Each complex of conditions is contributary; no complex of conditions is exclusively operating. This, we shall attempt to show, is because the inseparable action of all the four factors results either in: (1) the leading action of one factor in the building up of a new character or the modification of an existing character, or (2) in the combined and simultaneous action of all the factors on different groups of characters to bring about a harmonious and correlated result.

Finally, characters are to be understood in two senses:

First: what appears in individuals, varieties, and species, as observed by the describer or systematist.

Second: the unseen forces of heredity which underlie these appearances.

This profound distinction between the "character" as it appears to us as the soma and the "character" as it exists in the blastos is one which we owe to the studies in heredity of Galton, Weismann, Mendel, and Johannsen. It is expressed as follows:

Sum of characters of the soma = Heredity, Ontogeny, Environment.
Sum of characters of the blastos = Heredity.

The sum of "characters" in the soma has been aptly termed by Johannsen the *phenotype*, the sum of "characters," or "genes," in the blastos the *genotype*.

Into every organism we examine enter the three factors heredity, ontogeny, environment. It is easy to understand why the soma is more readily disturbed than the blastos, because every soma is the resultant of three factors, while the blastos is relatively undisturbed.

I. SPECIAL ACTION OF EACH OF THE FACTORS.

Biologists are in a general way familiar with what is comprised in each of the four factors under consideration, but the literature at least is so full of apparent misunderstanding that the author may be pardoned for elaborating somewhat his own interpretation of the precise biological or evolutional significance of each of these factors.

1. Environment.[1]

Under environment we should consider the sum total of purely inorganic and organic external conditions, with the exception of selection which forms a complex of its own; that is, conditions which are neither germinal nor somatic, which, however, as "conditions of life" affect the heredity, the ontogeny, and the selection or elimination of the individual. The older conceptions of the conditions of life, *Le milieu*, *La monde ambiente*, should be taken into consideration together with the "continuity of environment," that is, the continuation of inheritance of similar environment from generation to generation; in other words, with ancestral environment as contrasted with discontinuity of environment or the introduction of new or changed conditions.

It is impossible to make a complete classification of environment, but the following scheme, partially suggested by that of Max Verworn, is suggestive of the multiplicity of conditions.

It will be observed that organic environment brings us into close touch with the phenomena of competition and selection.

[1] Osborn, H. F., Environment in its Influence upon the Successive Stages of Development and as a Cause of Variation. Opening discussion before the American Society of Naturalists, Baltimore, Dec. 27, 1894. *Science*, N. S., vol. I, No. 2, Jan. 11, 1895, pp. 35–36.

I.	II.		
Inorganic.	Organic.		
A. Physical Conditions[1]	*B.* Food and Nutrition	*C.* With Individuals of the Same Kind[2]	*D.* With Individuals of other Kinds, Species,[2] Varieties, Genera, Etc.
Examples.			*Favorable* / *Unfavorable*
Physical conditions.	Nature of	*i. e.*, relations of parentage,	Cooperative / Hostile
Chemical conditions.	Chemical con-	of offspring, of various	Friendly / Competitive
Temperature.	stitution of	degrees of blood relation-	Commensal / Destructive
Heat.		ship, sexual and repro-	Symbiotic / Parasitic
Cold.		ductive relationships, of	Parasitic
Moisture.		similar sports, muta-	
Composition of water.		tions, varieties, species,	
Composition of atmos-		etc.	
phere.			

Some writers have grouped these relations with individuals of the same kind and with individuals of other kinds under selection, using that term in a too comprehensive sense, as including, for example, individual choice of environment, which is evidently not one of the modes of selection in the strict Darwinian sense.

The environment may migrate around an organism, as in the course of geologic change, while the organism may through force of circumstances migrate into a new environment. All the relations with (*C*) individuals of the same kind or with (*D*) individuals of other kinds may result in bringing organisms into a change of environment. This is especially true of animals in which psychic segregation, isolation, tradition, and imitation bring about changes of environment.

2. Ontogeny.[3]

Ontogeny is the visible expression of heredity as reacting to environment and selection. It includes all the phenomena of change in the individual development of organisms as a whole and in their parts. Ontogeny thus strictly begins with the fertilized ovum and includes all the internal changes in the life cycle, all somatic or somatogenic as distinguished from blastic or blastogenic conditions, all "acquired" or "nurture" conditions as distinguished from "inborn" or "nature" conditions. In a sense, as has recently been pointed out by Archdall Reid[4] in discussion with Lankester, all characters are acquired.

[1] As partly caused by geographical segregation, geographical isolation, geographical insulation or separation by water.

[2] As partly connected with segregation of kind, isolation of kind, consciousness of kind, traditions of kind, imitations of kind, etc.

[3] Osborn, H. F.: The Cartwright Lectures for 1892 before the Alumni of the College of Physicians and Surgeons, New York.—Present Problems in Evolution and Heredity. 1. The Contemporary Evolution of Man. 2. Difficulties in the Heredity Theory. 3. Heredity and the Germ Cells. *N. Y. Medical Record*, vol. 20, Mar. 5 and April 23, 1892. Alte und Neue Probleme der Phylogenese, Sep. Abdr. aus d. *Ergebnisse der Anatomie und Entwickelungsgeschichte* (von Fr. Merkel u. R. Bonnet, Göttingen), Band III, 1893, pp. 584–619.

[4] "... Obviously, all characters depend equally on an interaction between germinal potentiality and external stimulus. They are all, therefore, as inborn and acquired, as blastogenic and somatogenic as they can possibly be. No such things are conceivable as purely blastogenic and somatogenic characters, or characters which are more blastogenic or somatogenic than others." *Nature*, vol. 89, No. 2214, Apr. 4, 1912, p. 113.

Ontogeny in a sense stands midway between heredity and environment, that is, the somatic expression of purely hereditary forces depends both upon the continuity of environmental conditions and on the continuity in the ontogeny itself. If there is a revival of an ancestral or bygone environment, there may be more or less of a revival of ancestral ontogenic characters.

Wherever the environment or the ontogeny differs from its typical condition we discover somatic changes, which are variously known as modifications, somations, accommodations, individual adaptations. Some of the "variations" of Darwin and "fluctuations" of other authors are undoubtedly expressions of ontogeny rather than of heredity.

Ontogenic processes are so closely related with hereditary predispositions that it has often been difficult to draw the line between the predisposition and that which is added. The following summary includes the processes in which there appear to arise some of the chief ontogenic modifications of typical heredity.

1. Revival of ancestral (recessive or latent characters) through the revival of ancestral environment.
2. Acceleration in the rate of ontogeny through functional and other causes.
3. Retardation in the rate of ontogeny through loss of function and other causes.
4. Progressive individual development or "ontogenic development."
5. Retrogressive or "ontogenic degeneration."
6. Somations or modifications of the somatic cells through direct action of the physical environment.
7. Somations or modifications through the law of use and disuse.
8. Somations through changed social, reproductive, mutative, and traditional relations.
9. Somations through changes of function.[1]

[1] . . . We owe to Dr. Arbuthnot Lane a most interesting series of studies upon the influences of various occupations upon the human body. He proves conclusively that individual adaptation not only produces profound modifications in the proportions of the various parts, but gives rise to entirely new structures.

His anatomy and physiology of a shoemaker* shows that the life-long habits of this laborious trade produce a distinct type, which if examined by any zoölogical standard would be unhesitatingly pronounced a new species. The psychological analysis which a Dickens or Balzac would draw, showing the influences of the struggle for existence upon the spirit of this little shoemaker, could not be more pathetic than Dr. Lane's analysis of his body. The bent form, crossed legs, thumb and forefinger action, and peculiar jerk of the head while drawing the thread, are the main features of sartorial habit. The following are only a few of the results: The muscles tended to recede into tendons and the bony surfaces into which they were inserted tended to grow in the direction of the traction which the muscle exerted upon them. The articulation between the sternum and the clavicle was converted into a very complex arthrodial joint, constituting almost a ginglymoid articulation. The sixth pair of ribs were anchylosed to the bodies of the vertebræ, indicating that they had ceased to rise and fall with sternal breathing, and that respiration was almost exclusively diaphragmatic. The region of the head and first two vertebræ of the neck was still more striking: the transverse process of the right side of the atlas, toward which the head was bent, formed a new articulation with the under-surface of the jugular process of the occipital bone, "a small synovial cavity surrounded this acquired articulation, but there was no appearance of a capsular ligament"; the left half of the axis was united by bone to the corresponding portion of the third cervical; there was found a new

* *Journal of Anatomy and Physiology*, 1888, p. 595.

10. Accommodation or individual adaptation reflected in the above somations arising through plasticity, modifiability, or adaptability to new relations.

11. The "variations of Darwin" in part, including such fluctuations or changes of degree as are caused by use, disuse, and habit in distinction from those which are caused in the germ.

12. The "modifications" of Lloyd Morgan.

13. The "ontogenic variations" of Osborn.

14. Acquired or individual immunity.

15. Ontogenic fertility and infertility due to external and internal causes.

16. Somatic correlations acquired as distinguished from hereditary correlations.

17. Influence of "habitudinal selection," of individual choice, change of food, etc.

18. Intra-selection (Roux) or struggle between the parts of the organism.

19. Somatic or ontogenic environment of the germ cells.

20. Ontogenic balance of organs (St. Hilaire).

21. Ontogenic compensation of growth (St. Hilaire).

22. Somation or ontogenic adaptation affording the opportunity for "coincident variation" or "organic selection" (Morgan, Baldwin, Osborn).

23. Functional adaptation (Roux, *functionelle Anpassung*).

24. Physiological or second order correlations (Crampton).

Summing up all such ontogenic changes, which are partly pure expressions of heredity, partly heredity modified by ontogeny, we secure the following classification:

CLASSIFICATION OF ONTOGENIC CHANGES.

Hereditary Repetition of Type (Conservative).	Normal or typical growth, cytogeny, embryogeny, ontogeny.
	Recapitulation of ancestral history, under similar inherited conditions.
	Recapitulation of parental history, inherited conditions.
	Revival of ancestral characters through stimulus of revived ancestral environment.
	Somations through normal physical environment, tradition, incidence of selection, etc.
Readjustments (Retrogressive and Neutral).	Somations through abnormal or unfavorable action of physical environment, social relations, traditions, altered sexual relations, conditions of reproduction, etc.
	Fluctuations retrogressive.
Readjustments (Progressive).	Progressive development of organs through use.
	Fluctuations, progressive, due to use and habit, changed conditions.
	Abbreviations of ancestral history due to abbreviation of conditions.
	Ontogenic intercalations.
	Acceleration of ontogeny of certain organs through increased functions.
	Correlation to new conditions.
	Correlation to acquired conditions.
	Neomorphs, neogenesis, new characters.

Here may be introduced J. Mark Baldwin's definition of modification:

MODIFICATION (in biology) [Lat. *modificatio*]: Ger. (*individuell erworbene*) *Abänderung* (Wundt); Fr. *modification:* Ital. *modificazione.* A structural change wrought during the individual's lifetime

upward prolongation of the odontoid peg of the axis, and a new accessory transverse ligament to keep it from pressing upon the cord. In short, "the anatomy of the shoemaker represents the fixation and subsequent exaggeration of the position and tendencies to change which were present in his body when he assumed the position for a short period of time." (Osborn, H. F., *Medical Record*, 1892, pp. 35–36.)

(or acquired), in contradistinction from variation, which is of germinal origin (or congenital). . . . Organisms capable of extensive modification are termed plastic; and this Plasticity (q. v.) may be subject to selection. The term Accommodation (q. v.) is reserved by some writers for the moulding of behavior to environing circumstances on the part of organisms, referring to function rather than to structure. On the hypothesis of Organic Selection (q. v.) modifications of structure may serve to foster Coincident Variations (q. v.) of like nature, and accommodations of behaviour may thus set the direction of congenital variation, and so of evolution under the action of natural selection.

Literature: Lloyd Morgan, Habit and Instinct; J. Mark Baldwin, A New Factor in Evolution, *Amer. Natural.*, June–July, 1896; Headley, The Problems of Evolution (1901). [*Dictionary of Philosophy and Psychology*, vol. II., The Macmillan Company, 1902, p. 94.]

If we thus review ontogeny we are impressed, first, with the fact that it is the visible expression of heredity; second, that its range is enormous; third, that it is constantly inseparable from the other three factors, heredity, environment, selection. The opportunities for the initiation or origin of new characters in ontogeny is also very great through direct action of environment and actively in all those parts which depend upon movement for their development.

All species and varieties in the plastic or modifiable parts of their organization are in a sense ontogenic.

If the sum of changes involved in ontogeny is normal or typical, the individual (unless abnormal through heredity or environment) is normal. Any abnormality in the sum of changes involved in ontogeny may produce an abnormal, or atypical individual.

There is in a sense, therefore, an evolution of the soma under a discontinuous ontogeny and discontinuous environment which is quite distinct from the continuous evolution of the blastos.

There is in all organisms more or less disharmony, or dysteleology between the evolution of the soma and the evolution of the germ; the former is in many respects more progressive, the latter more conservative.

The following general observations and points may be made partly in recapitulation of the above. These points are suggestive of experiment and of further inquiry.

1. Ontogeny is not separable from heredity; it is to be regarded as the expression of heredity as reaching to and modified by the conditions of life, of environment and of selection. Ontogeny results in the sample organism which is put to the test of selection.

2. Thus normal, or typical ontogeny, *i. e.*, repetition, is dependent on typical heredity, typical activity of the organism, typical organic or inorganic environment, undisturbed social relations and undisturbed incidence of selection. Thus ontogeny affords a complete illustration of the inseparable factors of life.

3. Atypical ontogeny is caused by the same relations in abnormal form.

4. Further, ontogeny is a test of heredity since it involves a process of internal elimination and selection, or approval of the changes offered by heredity.

5. We express in the terms "variability," "modifiability," "plasticity," "adaptability," etc., the powers of the organism to readjust itself to new circumstances.

6. These powers, as we have seen, under heredity are themselves partly hereditary and transmissible; that is, individuals partly through heredity differ in their powers of plasticity toward one or more new conditions.

7. Individual adaptation, or accommodation, represents in part the result of different degrees of plasticity.

8. It also remains to be determined positively whether new ontogenic characters are not in certain degree handed down to the blastos as well as to the soma.

9. Generation after generation new ontogenic characters may be handed down in the soma which have no counterparts in the blastos; they would nevertheless by naturalists be reckoned among specific or varietal characters.

10. It remains to be determined in what true sense ontogeny may be a factor of evolution, *e. g.*, through "coincident" or "organic selection" even with the exclusion of the transmission of new ontogenic (somatogenic) characters.

11. Under ontogeny should be considered the influence on the soma of segregation, geographical and habitudinal, of isolation.

12. Under ontogeny should be considered also all the laws of growth, such as abbreviation, acceleration, retardation, development, degeneration, persistence or stability of parts.

13. Ontogeny should also be considered in its discriminating, guiding, and selecting action.

14. We should also consider how far there is through retarded or imperfect adjustment in heredity to new conditions of life (*a*) a continuous evolution of the soma as quite distinct from the continuous evolution of the germ plasm and how far (*b*) this is responsible for the disharmony, or dysteleology in the human subject, for example.

15. As regards adaptability, plasticity, modifiability, these are the essential initiating conditions not only of modifying certain organs but of originating certain organs, changes of function, etc. There is a difference of theory regarding plasticity, whether it is inherent in all living matter or whether the power of plastic adaptation to new conditions is not part of a revival of hereditary powers which were previously exercised under somewhat similar conditions. Plasticity in relation to selection raises the question as to the survival of the most plastic and most readily modifiable organism, or the organism which is most readily modifiable in the course of ontogeny.

16. In experiment and investigation somations or modifications should be considered under four aspects:

(*a*) As affecting heredity primarily, in which the influences are less clear and rapid.

(*b*) As affecting ontogeny primarily, in which the influences are most clear and rapid.

(*c*) As affecting both heredity and ontogeny simultaneously.

(*d*) As affecting ontogeny then heredity.

17. A matter for investigation also is whether the development of function invariably precedes the development of structure, whether physiological development precedes morphological development, whether the evolution of function precedes the evolution of structure. Take, for example, the evolution of the horns in cattle; three distinct complexes of character are involved as follows:

(*a*) Psychic, the desire to butt or use the horns.

(*b*) Epidermal, the corneous sheath surrounding the horn.

(*c*) The osseous protuberances of the skull.

On the Lamarckian hypothesis the psychic desire to use the horn precedes the development of the corneous sheath and of the osseous horn. In the actual embryonic development the formation of the corneous sheath in the Bovidæ precedes that of the osseous horn. In the case of the genesis of the horns in the titanotheres the first appearance is that of the osseous horn as a swelling; it is impossible to say whether this structure was preceded by the psychic desire to use a certain part of the skull in butting. In the development of cusps on the molar teeth it would appear that these structures must precede the functions which they would subserve.

Ontogeny, development and degeneration of parts, is generally found to precede development and degeneration in heredity.

18. In general it would appear that the *psychic evolution of habits must either be coincident with or precede the morphologic evolution of organs*, because most organs in order to develop in ontogeny and come under the influence of selection or elimination must first be selected or eliminated by habits in ontogeny. An organ arising through heredity (a variation, mutation, saltation) but unused in the course of the life of the individual could not have any utility value and therefore would not be affected by selection. In this sense ontogeny plays an important part in selection; that is, ontogeny is *inseparable* from selection.

19. *Fluctuations.*—It is important to note that certain fluctuations apparently due to heredity may be due to ontogeny, that is, to causes favorable or unfavorable affecting ontogeny of certain parts. Therefore it is difficult in many cases to measure fluctuations as the expression of heredity and exclude the ontogenic influence.

20. Fluctuations in certain organs are not due invariably to hereditary fluctuations in those organs, but to fluctuations in other organs. For example, consider the occasional enlargement of the heart and arterial system as an hereditary fluctuation, which, for instance, in the case of the race horse "Eclipse," weighed 14 lbs., partly explaining the extraordinary endurance and speed of this animal.

21. Correlation by somation adjustment or accommodation is a phenomenon distinct from correlation by heredity; for example, Herbert Spencer cited correlation of the muscles and bones of the neck in the great Irish deer *Megaceros* as proof of the transmission of acquired correlated characters. The argument is fallacious because similar correlation would be brought about in the head of other deer by attaching a heavy weight permanently to the top of the head, which

would bring about an increase of size in the muscles and bones of the neck and shoulders entirely analogous to that observed in *Megaceros*. This may be an ontogenetic adaptation.

3. Heredity, including Variation.[1]

By heredity we mean the forces or conditions embodied in the "stirp" of Galton, in the "germ plasm" of Weismann, in the "genes" of Johannsen, in the "determiners" or "factors" of other authors. We use heredity in this sense as one of the four factors rather than coin a new name. That is, heredity is conceived as the continuity of forces resident in the blastos rather than in its outward or visible expression in the soma as what are known as hereditary characters. Thus heredity includes the germinal, blastogenic, congenital or native conditions of "nature" as distinguished from the "nurture" conditions. It is the seat of the behavior of all the characters which are transmissible or heritable.

Heredity, as is clearly understood by some authors and not by others, includes both hereditary repetition and hereditary variation, as distinguished from ontogenic variation. Thus variation is an included principle within heredity and not an opposed principle. There is no reason in the often repeated phrase that "evolution is through heredity, variation, and other factors."

While heredity is chiefly remarkable as the conservative force, palæontology proves that there is a strong progressive element in it; that is, in some unexplained manner new properties and potentialities are constantly being added to the blastos, or material basis of heredity.

Some of the ontogenic or phenotypic "characters" which are the outward expression of the predispositions and potentialities of heredity are the following:

1. Repetitions of parental and ancestral type = the heredity of some writers, including "characters" occurring late in life which are apparently somatogenic but in reality blastogenic.
2. Predispositions, structural and functional.
3. Recapitulations of ancestral history,
   (*a*) regressions,
   (*b*) reversions.
4. Abbreviations of ancestral history, intercallations.
5. Fluctuations in plasticity, modifiability, adaptability.
6. Fluctuations in susceptibility of immunity to certain diseases.
7. Correlations of (*a*) functionally related characters, (*b*) functionally unrelated characters.
8. Variations of Darwin in part = Mutations.[2]
   Also variations of Darwin in part = Fluctuations.
9. Heredity, fluctuations in Quetelet's and Galton's sense in all characters.
10. Recessives (Mendel), also latent characters in part (Galton).
11. Dominants (Mendel), also patent characters in part (Galton).
12. Contemporaneous and sudden variations not following the Quetelet law, including "fortuitous variations," "saltations," "sports," "mutations" of De Vries (not of Waagen).

[1] Osborn, H. F.: Evolution and Heredity. *Biological Lectures, Marine Biological Laboratory*, Woods Hole, 1890. Ginn & Company, Boston. Are Acquired Variations Inherited? Opening a discussion upon the Lamarckian Principle in Evolution. American Society of Naturalists, Boston, Dec. 31, 1890. *Amer. Naturalist*, vol. XXV, No. 291, Mar. 1891, pp. 191–216. The Present Problem of Heredity, *Atlantic Monthly*, Mar., 1891, pp. 353–364. Heredity in the Ovum and Spermatozoon. *Wood's Reference Handbook of the Medical Sciences*, pp. 396–408. W. Wood & Co.

[2] Osborn, H. F., Darwin's Theory of Evolution by the Selection of Minor Saltations, *Amer. Naturalist*, vol. XLVI, Feb., 1912, pp. 76–82.

13. "Mutations of Waagen,"[2] 1869, or continuous variations in time.
14. "Mutations of De Vries."[1]
15. "Definite variations," Osborn (1891).
    "Phylogenic variations," Osborn (1893).
    "Rectigradations,"[2] Osborn (1905).
16. Potential homologies [non-Homoplasy], Osborn (1902).

The recent distinction of Johannsen between the "genotype," or genetype (Osborn) as an assemblage of genes and the phenotype is also the distinction between heredity, as here conceived, and ontogeny.

Ontogenic, phenotypic, or somatic expressions of heredity may be roughly classified as follows:

- Classification of the somatic expressions of heredity.
  - Repetitions of type.
    - Recapitulations of ancestral history.
    - Ancestral predispositions.
    - Ancestral correlations.
    - Regressive fluctuations, or deviations around a mean.
    - Regressions.
    - Reversions.
    - Ancestral dominants and recessives.
  - Slow progress or alterations of type.
    - Germinal modifications.
    - Progressive fluctuations, or deviations around a mean.
    - Mutations of Waagen.
    - Phylogenic variations.
    - Rectigradations of Osborn.
    - Phylogenic degeneration, development.
  - Sudden alterations of type.
    - Saltations, sports.
    - Neogenic characters or neomorphs.

The "potential homology" of Osborn (1902) is one of the most mysterious manifestations of the forces of heredity, which predisposes descendants of a similar stock, however remote, to give rise to similar new characters through heredity. This principle, which the author considers to be absolutely demonstrated in the case of the evolution of the teeth and of the horns of the titanotheres, has also been less positively observed by other zoologists as well as by botanists. Recent investigators of the mutation phenomena of De Vries have remarked the tendency of plants to give rise to similar new "mutants" in widely separated localities. It is noteworthy that this principle was clearly recognized by Darwin in his *Origin of Species:*

> . . . The principle formerly alluded to under the term of *analogical variation* has probably in these cases often come into play; that is, the members of the same class, although only distantly allied, have inherited so much in common in their constitution, that they are apt to vary under similar exciting causes in a similar manner; and this would obviously aid in the acquirement through natural selection of parts or organs, strikingly like each other, independently of their direct inheritance from a common progenitor.[2]

Considering the ontogenic expressions of heredity as they appear in palæontological series, we may repeat our statement above that blastic evolution is the most mysterious and also the most elusive of phenomena so far as are concerned the laws which govern the orderly origin and appearance of new characters.

We note the following significant questions for investigation:

[1] "Mutations" of Waagen and "Mutations" of De Vries or [and] "Rectigradations" of Osborn. *Science*, N. S., vol. XXXIII, No. 844, Mar. 3, 1911, p. 328.

[2] Origin of Species, vol. II, p. 221. Edition of 1909, D. Appleton & Co., 2 vols. in one.

1. Is it true that the greater number of new or *germinal characters* which appear are *orderly and according to some entirely unknown law* of adaptation? Or is it true that the greater number of new characters are accidental, disorderly, fortuitous, adaptive or inadaptive, fitted or unfitted, and that order comes out of chaos by the selection of those which happen to be fit? This question or questions, as old as Empedocles, the crucial point in Darwin's philosophy, is still a matter of investigation by the rigid analysis of the origin of new characters in relation to the principle of the four factors.

2. Is it true that the greater number of new characters of evolution first appear in heredity; or is it rather true that the greater number of new characters first appear in ontogeny and subsequently in heredity?

3. Is it true that blastogenic evolution lags behind ontogenic or somatic in certain structures, organs, and modes of change?

4. What are some illustrations of the slow action of heredity, that is, where heredity seems to lag behind ontogeny? What are some of the illustrations of the rapid action of heredity, that is, where heredity seems to precede or anticipate ontogeny?

5. Are differences first appearing in ontogeny identical with those which subsequently appear in heredity?

6. What primarily ontogenic characters become fixed in heredity and what remain purely ontogenic?

Special Aspects of Heredity.

Repetition of type, the heredity *par excellence* of many authors, is equivalent to likeness of type, stability of type, breeding true to type, to the principle that like produces like, in short, to the conservative principle of heredity and a large number of expressions of this conservative principle. In studying environment and ontogeny it has been made clear, however, that repetition of type depends upon repetition of ontogeny, repetition of environment, and repetition of selection.

Correlations in heredity are (*a*) of similar or like parts, such as of strong muscular and bony systems, or (*b*) dissimilar or unlike parts, as, for example, the correlation of speed with bay color in thoroughbred horses. We now understand through the laws of "particulate inheritance" of Galton, or "unit character" inheritance of Mendel and of Bateson that characters depend upon certain theoretic "determiners" in the blastos, the association of which conditions these correlations.

Fluctuations in Heredity.—These include in part the variations of Darwin, variations of degree, plus and minus variations, the fluctuations around a mean, the "continuous variations" of Bateson, the "allometrons," or differences of proportion, of Osborn, so far as all of the above are blastogenic rather than somatic in origin.

The following notes as to fluctuations of character may be made:

1. It is desirable but often very difficult to distinguish between fluctuations which originate in heredity and those which originate in ontogeny. For example, (*a*) certain bodily fluctuations, such as of the bones and muscles, may not be due to heredity, but may be the anatomical expression of hereditary fluctuations in the brain and nervous systems; for instance, the strong, active flight of the bird, which generates strong muscles and large, well developed bones, may originate either in (*a*) fluctuations of those germ cells which give rise to those tissues, or (*b*) in fluctuations of those germ cells which give rise to the nervous system.[1]

2. Environment may also exert a marked influence on ontogenic fluctuations and cause them to appear as hereditary fluctuations.

3. Marked anatomical changes produced by fluctuations in habit again may find ontogenic (therefore non-inheritable) fluctuations in the anatomy.

4. It is now questioned whether there are chromosomal or germinal fluctuations in the true sense.

Under characters of sudden origin, or saltations, we certainly must include in part the "individual differences" of Darwin, also in part the "new characters" of Darwin. These saltations have also been called "fortuitous variations," "sports," "discontinuous variations" (Bateson). They are equivalent to the "mutations of De Vries" but not to the "mutations of Waagen."

The fact that these saltations are for the most part pure phenomena of heredity is demonstrated by their hereditary stability. The question of the *fortuitous*, that is, the indiscriminately adaptive and inadaptive character of saltations, is a very important one. De Vries speaks of his "mutations" as fortuitous in this sense and as preserved or destroyed by selection.

4. SELECTION.

Selection is not an active or creative factor in the sense of *originating* changes. In the strict sense it acts upon the changes which are initiated by either environment, ontogeny or heredity; it conditions the outcome in survival or elimination of the adjustments of internal and external relations; it thus acts as a sieve upon the results of the interactions of environment, ontogeny, and heredity. Darwin's own conception of the outcome can never be improved, namely, that this adaptation or non-adaptation means success in the struggle for existence (through ontogeny) and in leaving descendants (through heredity). Organisms which would be eliminated under the safeguards afforded by heredity alone may be saved through ontogeny, that is, through adaptability to new conditions.

That the Darwinian sense of the word selection is the true sense is shown by the misuse of the term. Under selection should not be included such processes as "intra-selection" or "functional selection," which are purely ontogenic; nor of "coincident selection" or "organic selection" (Morgan, Baldwin, Osborn), which are joint processes of ontogeny, or heredity, and of selection in the sense

[1] Analogy with man shows that these muscular, bony, and nervous fluctuations are not necessarily correlated.

in which we are using these terms. Thus the classification of selection by J. Mark Baldwin includes a number of processes which belong to ontogeny only.

The processes which belong strictly to selection are the following:

Human, or artificial selection.

Natural selection, survival of the fittest.

Elimination, destruction of the unfit.

Cessation of selection, panmixia.

Coincident or organic selection in part.

Sexual selection, the choice of mates.

The "germinal selection" of Weismann simply expresses the fact that natural selection acts upon the ontogenic and environmental reactions, predispositions and potentialities of heredity.

The following citations from Castle's recent work[1] afford a concrete illustration of the potency idea:

"... But there occur also cases in which the varying gametic potency is associated directly with the character affected. One such I was able to describe in 1906—that of an extra toe in guinea-pigs. It was found while building up a polydactylous race by selection and crossing with other races that individuals varied in the potency which the character had in their gametes. In general the better developed the character was in an individual the more strongly was it transmitted, *i. e.*, the larger was the proportion of polydactylous individuals produced in crosses. In no case, however, was this a recognizable Mendelian proportion, though both dominance and segregation seemed to be taking place. Variation in potency was, however, unmistakable and was transmitted from generation to generation."[2] See Fig. 36 (pp. 100–101).

"Great as has been the contribution of Mendelian principles to our knowledge of heredity, they do not reduce the whole art of breeding to the production of new combinations of unit characters through crossing. Selection is required also, not merely among different combinations of unit-characters, but also among individuals representing the same combinations selection is required of those possessing the desired characters in *greatest potency*" (pp. 104–105).

"From the evidence in hand we conclude that Darwin was right in assigning great importance to selection in evolution; that progress results not merely from sorting out particular combinations of large and striking unit-characters, but also from the selection of slight differences in the potentiality of gametes representing the same unit-character combinations. It is possible to ascribe such differences to little units additional to the recognized larger ones, but if such little units exist, they are indeed very little as well as numerous, and by adding to the effect of the larger ones they produce what amounts to modification of them" (pp. 126–127).

Coincident Selection.

The term "coincident selection," suggested by Lloyd Morgan, seems to be more expressive of the principle than the term "organic selection" proposed by Baldwin for the Baldwin-Morgan-Osborn hypothesis. As this is one of the illustrations of the law of the inseparable factors it is treated below (p. 302).

Baldwin[3] offers the following definition of cessation of selection, or panmixia:

"Panmixia [Gr. πᾶν all, + μῖξις, a mixing]: Ger. *panmixie;* Fr. *panmixie;* Ital. *panmissia.* Promiscuous interbreeding within the limits of a species or other group as contrasted with breeding under artificial selection or other form of isolation."

[1] Castle, Wm. E., 'Heredity in Relation to Evolution and Animal Breeding.' 8vo. D. Appleton & Co., 1911, 184 pp.

[2] An alternative explanation is possible, viz., that the development of the fourth toe depends upon the inheritance of several independent factors, and that the more of these there are present, the better will the structure be developed. The correctness of such an interpretation must be tested by further investigations.

[3] Baldwin, J. Mark, Dictionary of Philosophy and Psychology, vol. II, The Macmillan Company, 1902, pp. 255–256.

"Romanes drew attention to the effects of cessation of selection, which involves the perpetuation of mediocrity. Weismann laid stress on the promiscuous interbreeding which results, and termed it panmixia. The dwindling of vestigial organs was attributed by both authors in large degree to panmixia with cessation of selection. Lankester and others contend that, in the absence of other factors, there could be no dwindling beyond the existing birth-mean of the species, and economy of growth and germinal selection have been suggested as additional factors. Pearson claims to have demonstrated, mathematically, that 'panmixia without active reversal of natural selection does not lead to degeneration' (on the basis of Galton's law, p. v., of ancestral heredity). Cf. Amixia."

Soon after the enunciation of the doctrine of the continuity of the germ plasm by Weismann there was extended discussion of all the phenomena of selection. At this time, in the reaction from Lamarckism, the effects of environment and ontogeny were considered of subordinate importance and the efficiency of heredity and of selection as the all-important factors of evolution was the dominant biological teaching.

II. INTERACTION OF THE FOUR FACTORS.

Having considered the special action of each of the four factors we may now take up the interactions. Each factor has its especial rôle in these interactions. Thus ontogeny, or the soma, alone enjoys what may be called the experience of environment and selection; through ontogeny alone heredity is tested; change of habits, ontogeny, and consequent modification, in the experience of new environment, leads the way ultimately to changes in heredity. On the contrary, a saltation or mutation in heredity, the sudden appearance of a new habit or of a new function, will immediately be reflected in a new course of ontogenic changes and perhaps in the choice of a new environment.

What may be called the prevailing relations of the four factors in respect to the origin and history of new characters and habits would appear to be as follows:

Factors.	*Chief Action as to Characters.*
ENVIRONMENT	Initiation of new conditions in ontogeny and heredity.
ONTOGENY	Adjustment of heredity to environment, experiment with hereditary predispositions, ontogenic origins of characters.
HEREDITY	Genesis, continuous or discontinuous origins of new characters.
SELECTION	Fixation of characters and determination of the trend or direction from which new characters accumulate.

I. LIFE.		II. CONDITIONS OF LIFE.	
Including all characters new and old and the exciting and originating causes of many characters.		Including the exciting, originating and eliminating causes of many characters belonging in I.	
Purely Internal Relations.		Purely External Relations.	External and Internal Relations.
Heredity.	Ontogeny.	Environment.	Selection.
Entire life of the germ cell and germ plasm, including fertilization, germinal variation, etc.	Entire life of the body cells from fertilization to death.	Entire surroundings of the individual life. (*A*) *organic*, social or of kind. Animal and plant life not of kind. Nutritive. (*B*) *inorganic*.	Struggle for existence. Survival of individual life and multiplication by progeny.

These interactions may be very simply expressed as follows:

HEREDITY × ONTOGENY × ENVIRONMENT × SELECTION = INDIVIDUAL.

The use of the multiplication sign (×) is a very gross and partly misleading method of expressing *the interactions or complexes of conditions which exist.* For example, selection operates upon the resultant of the interactions of environment, ontogeny, heredity.

The simplest applications of this formula are as follows:

Heredity × normal activities of life × normal environment × normal incidence of selection = stability or persistence of type.

Or again,

Heredity exhibiting variation × changed or changing activities of life × changing environment × changing incidence of selection = a change of type.

Another method of expressing the interactions between these four sets of conditions is the following:

	I. HEREDITY.	II. ONTOGENY.	III. ENVIRONMENT.	IV. SELECTION (COMPETITION).
Physical Basis.	Germ-plasm.	Germ-plasm and somatoplasm.	Animate and inanimate surroundings.	
A The Unknown *Factors*, or Interactions.	Sum total of the forces and laws operating in the germ plasm.	Sum total of the laws and forces operating in the development of the individual.	Sum total of the influences of the inorganic and organic surroundings, including social, racial and non-racial factors.	Sum total of the struggle for existence. Success in obtaining food, mating and leaving progeny.
B The known, or observable *Modes* of Expression in the Phenotypes.	Generally conservative, subject to slow changes. Repetitions of type, "fluctuations," "saltations," "mutations," etc.	Accommodations, modifications, fluctuations, somations, generally subject to rapid and extreme changes.	Migration, isolation, segregation, insulation changes varying from slow to extremely rapid.	Elimination. Struggle for existence, varying from slow to extremely rapid changes.

The significance of the term *interaction* was clearly brought out in the writer's first statement of the law in 1907 before the Section of Palæozoology of the Seventh International Zoological Congress.[1] This statement was as follows:

"I desire to introduce this paper by the statement of a law which seems to be axiomatic, although it is largely ignored by biologists. I may term it the *law of the four inseparable factors.*

"These four factors in the life of organisms are known to us under the terms heredity, ontogeny, environment and selection. The following statement regarding these factors expresses the whole truth:

"1. The life and the evolution of organisms invariably center around processes which, in our observations, are grouped under heredity, ontogeny, environment and selection.

"2. These have been inseparable and interacting from the beginning.

"3. A change introduced through any one of these factors causes a change in all.

"This I believe to be the most fundamental law of biology; far more fundamental than the well-

[1] Evolution as it Appears to the Paleontologist. Address before the Seventh International Zoological Congress, Section of Paleozoology. *Science*, N. S., vol. XXVI, No. 674, Nov. 29, 1907, pp. 744–749. *Proc. 7th Intern. Zool. Congr.* (Meet. Boston, 1907), 1912, pp. 733–739.

known biogenetic law. Yet a survey of recent discussion among biologists as to the theory of evolution shows broad lines of division into several schools of opinion strictly according to the factor from which the subject has been approached. It is true that, conceiving any one of these principal factors as separable, we become involved in endless difficulties; conceiving them as inseparable and continuously interacting under natural conditions, we reach the only true conception of the evolution process. Of these four factors *selection* is the only one which can be experimentally removed through the agency of man; heredity, ontogeny and environment may be modified but they can not be removed.

"I shall not stop here to demonstrate, as I shall do elsewhere, that changes may be initiated or find a gateway through any one of these four factors; I shall state simply that under certain circumstances heredity, under other circumstances ontogeny, under still others environment, or finally under selection, a new order of adjustments begins in animals and plants and a new series of characters appears. When such a new order sets in through any one of these factors a readjustment of all the others sooner or later ensues."

The second statement of the law, made before the Society of Zoologists at the New Haven meeting, December, 1907, was an amplification of the first.[1] It was as follows:

"The actual state of living nature is that of the *inseparable* and continuous action of these several factors as expressed in the following most fundamental biological law:

"*The life and evolution of organisms continuously center around the processes which we term heredity, ontogeny, environment, and selection; these have been inseparable and interacting from the beginning; a change introduced or initiated through any one of these factors causes a change in all.*

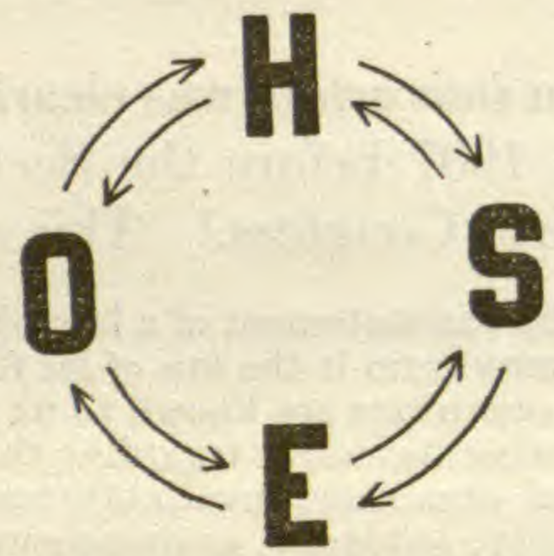
"Representing these processes respectively by the capital letters H, O, E, S, life and evolution may be represented by the formula:

$$H \times O \times E \times S.$$

"This formula roughly expresses the intimate nexus which exists between all these processes, a nexus which is quite consistent with the fact that each has also its separate part in life and in evolution. The multiplication sign, $\times$, is to be interpreted in the active and passive sense of *influencing and influenced by*. As examples of what is meant by this formula we may cite such principles as the following: (1) that heredity is conditioned by ontogeny and environment; (2) that selection operates on the product of heredity, ontogeny and environment; (3) that ontogeny initiates many changes which are subsequently taken up by heredity; (4) that of the four processes involved in life and evolution heredity is by far the most conservative and stable, among other reasons because it is embodied in a form of matter (germ-plasm) least subject to changing external influences; that ontogeny, on the other hand, is the most unstable.

"In contrast to the graphic representations of the original extreme hypothesis of Weismann, in which heredity is represented as a continuous current more or less isolated from ontogeny and environment there may be presented the following diagram.

"This diagram brings out the real cause of the difficulties which arise, as illustrated below (1–4), when we attempt to determine at what point in the chain of processes a new character is set in motion, in course of investigation of the initiation or origin of new characters."



"Diagram illustrating the reciprocal influences of heredity, ontogeny, environment, and selection. Arrows *across* the circle would represent these relations still more completely."

[1] The Four Inseparable Factors of Evolution. Theory of their Distinct and Combined Action in the Transformation of the Titanotheres, an Extinct Family of Hoofed Animals in the Order Perissodactyla. *Science*, N. S., vol. XXVII, No. 682, Jan. 24, 1908, pp. 148–150.

The words *influencing* and *influenced by*, which convey the significance attached to the interactions of the factors, bring us back to John Stuart Mill's argument that *the cause of anything is the total assemblage of the conditions that precede its appearance, but we have no right to give the name of cause to one of them exclusively of the others:* or, more fully, that the *cause* is the "sum-total of the conditions, positive and negative, taken together, the whole of the contingencies of every description, which being realized, the consequent invariably follows."

This doctrine formulated by Mill without specific reference to biological phenomena but in relation to physical phenomena in general, nevertheless expresses in the clearest possible manner the significance which we here attach to the words *inseparable factors.*

Thus excluding the ordinary arithmetical significance of the multiplication sign, we may use it merely as a convenient symbol for the present conception.

Similarly, the four factors may be symbolized by four capital letters, as follows:

Heredity, H or **H**
Ontogeny, O or **O**
Environment, E or **E**
Selection, S or **S.**

A method of representing the factors graphically is to use a light face letter, *e. g.*, H, for the stable and normal condition, and a heavy face letter, *e. g.*, **H**, for an abnormal or changed condition. The sequence, or order is indicated by the numerals 1, 2, 3, 4. For example:

H × O × E × S = a stable, typical, and normal condition.
H × O × **E**¹ × S = a change initiated in environment.
H × **O**² × **E**¹ × S = a change in environment with a corresponding change in ontogeny.
H × **O**² × **E**¹ × **S**³ = a change of environment, with a corresponding change in the ontogeny favored by ontogenic selection.
H⁴ × **O**² × **E**¹ × **S**³ = a change of environment, with a corresponding change in ontogeny, with consequent selection, accompanied by a favorable "coincident evolution" in heredity.
H¹ × **O**² × E × S = a discontinuous variation, saltation or mutation arising in the germ cells (heredity) and expressing itself in ontogeny.
H¹ × **O**² × E × **S**³ = a saltation in heredity, expressed in ontogeny and made permanent by selection.
H¹ × **O**² × **E**⁴ × **S**³ = a saltation in heredity, expressed in ontogeny, made permanent by selection, leading an organism into a new environment.

The above formulæ are convenient because they clearly express our ideas or the results of experiment as to the initial and consequent primary and secondary relations of the four factors.

Through the *Law of the Inseparable Factors* we are prepared to enter upon any form of experimental work or any line of exact observation or statistical inquiry with a perfectly clear understanding of how our facts should be collected and under what group or groups of factors they should be placed. (See Appendix, p. 307.)

Changes either in the form or in the origin of new characters are not simultaneously initiated by the four factors; on the contrary, we are prepared to answer the following inquiries:

(*a*) Under what conditions are new characters or modifications of character initiated?

(*b*) Do such new characters appear to be initiated by one factor or simultaneously by two or more factors?

Many of the conclusions which have hitherto been drawn, especially by field naturalists as to the initiation of new characters appear to assume that it is an easy matter to determine the point of initiation. As a matter of fact it is often extremely difficult to determine the point of initiation.

This raises the distinction between *initiation* and *genesis*.

1. Initiation and Genesis.

Initiation and genesis of characters are different phenomena. Initiation or the series of causes which precede the genesis of a new character may lie either in environment, in ontogeny, in selection, or in heredity. Somatic origins or genesis may be found in ontogeny, as expressed in the word somatogenesis. Blastic origins, or true genesis can occur only in heredity or in blastogenesis.

If each factor is conceived as influencing every other, the question in what part of the circle or chain of causes a disturbance begins which results in the appearance of a new character is often a very difficult one. We must not confuse a new character with one which is recalled from a latent condition by the revival of an ancestral environment. For example, the under surfaces of flat fishes is apparently white, or unpigmented; the action of sunlight on this white surface, however, reveals the fact that the ancestral pigmented character still persists and may be called forth as a reaction to sunlight. This is not a new character, it is simply a revival of a character which is latent not only in heredity, but in ontogeny.

The question of initiation is also difficult in heredity. For example, a "mutation of De Vries" is apparently initiated in heredity, but the experiments of MacDougal, Tower, and others, show that initiation is to be sought in the influence of environment on the germ cells. Similarly we may look for other experiments which will prove that certain saltations may find their initiation in ontogenic changes which reflect the germ cells, these in turn being due to environmental changes through a chain of causation. The inquiry as to initiation will in a measure harmonize the apparent discrepancies between the results obtained by those extreme observers (p. 282) who have centered their attention on a single factor to the exclusion of the consideration of other factors.

From the above considerations we may express the general law somewhat as follows:

In a state of nature at no stage is any one of the factors released from the operation of all the others. Every animal represents its heredity visibly expressed in and influenced by its ontogeny, its environment, and its selection. The normal balance of life in an organism being analogous to the normal balance of nature, the least disturbance of one of the factors produces a disturbance in all.

If this general principle is a sound one, it follows:

First, that working hypotheses which treat of the internal and external factors as separable phenomena are unsound.

Second, that all methods of investigation or experiment which proceed upon such hypotheses are unsound.

Third, that granting the general truth of the law of the inseparable factors, investigation and experiment will be directed upon the following specific inquiries:

(*a*) Under what conditions are readjustments initiated?

(*b*) Are readjustments initiated (1) by one factor or (2) by more than one, or (3) by a combination of the factors, or (4) under certain conditions by one factor and under other conditions by another, and thus possibly by each of the factors in turn?

One of the best illustrations of the difficulty of determining the point of initiation is exhibited by the time-honored problem of the inheritance of acquired characters, or the transmission of the effects of use and disuse. In such instances we observe the following parallelism as regards many characters:

Ontogeny.	*Heredity.*
Ontogenic development.	Ontogenic development.
Phylogenic degeneration.	Phylogenic degeneration.
Fluctuations arising from body cells.	Fluctuations arising from germ cells.
Neomorphs originating in body cells.	Neomorphs originating in germ cells.

The question whether this kind of ontogenic initiation or somatic genesis of character has any bearing in heredity is of course the crucial Lamarckian question.

So far as the law of the inseparable factors is concerned we must constantly remind ourselves that this kind of ontogenesis is a constant phenomenon in a state of nature, not an exceptional one, that *any animal forced into new or unusual environment under the stress of which new ontogenic characters are appearing will produce these characters generation after generation and that such characters will be regarded by the systematist as of taxonomic value.* Ontogeny is in this sense *initiative* exactly as environment is initiative.

2. Initiation in Environment.

The initial influence of environment in the modification of characters is part of the ancient doctrine of Buffon. It has been beautifully illustrated recently in the interesting experiments of Beebe[1] conducted in the New York Zoological Park, in which the eggs and young of the same mother bird were subjected to two extremes of environment, resulting in the ontogeny of two types of plumage. Here the formula of the inseparable factors is clearly the following:

$$H \times O^2 \times E^1 \times S.$$

[1] Beebe, C. William, Geographical Variation in Birds with Especial Reference to the Effects of Humidity. *Zoologica*, N. Y. Zool. Soc., vol. I, No. 1, Sept. 25, 1907.

In other words, in the first generation at least heredity is not affected, and since the experiment was conducted under artificial conditions, there was no selection. The experiments concurred with the observation of naturalists that the pigmentation of the plumage of certain birds is intensified in regions of warm and humid atmosphere. In *Scardafella inca,* on which the most complete series of experiments was made, the changes took place only at the moults, whether normal and annual or artificially induced at shorter periods. There was a corresponding increase in the choroidal pigment of the eye. At a certain advanced stage of feather pigmentation a brilliant iridescent bronze or green tint made its appearance on those areas where iridescence most often occurs in allied genera. Thus, as Beebe remarks, in birds no less than in insects characters previously regarded as of taxonomic value can be evoked or withheld by the forces of the environment.

Another example may be given from Castle: [1]

"Conditions other than the character [heredity] of the gametes themselves may determine the extent to which a character developes in the zygote, *i. e.*, the completeness or incompleteness of its dominance in a particular case. For example, in salamanders, which apparently, like mammals, form skin-pigments of different sorts, such as yellow, brown, and black, Tornier has found that by feeding [environment] one may control the proportions in which chromatophores of the several sorts are formed in the skin. Abundant feeding causes preponderance of pigment [ontogeny] of one sort, scanty feeding causes preponderance of pigment of another sort. Here external conditions determine the degree of development of characters . . . " (pp. 101–102).

3. Initiation in Ontogeny. [2]

Some of the best illustrations of initiation in ontogeny are those which may be selected in connection with the hypothesis of "organic selection" or "coincident selection," independently formulated at the same time by Baldwin, Morgan, and Osborn. Baldwin's statement of the hypothesis is as follows:[3]

Organic (or Indirect) Selection: Ger. *organische* or *indirekte Selektion;* Fr. *selection organique* or *indirecte;* Ital. *selezione organica* or *indiretta.* The theory that individual modifications or accommodations may supplement, protect, or screen organic characters and keep them alive until useful congenital variations arise and survive by natural selection. Cf. Coincident Variation, and Modification. The theory of evolution which makes general use of organic selection is called Orthoplasy (q. v.).

The theory, it is evident, involves two factors: (1) the survival of characters which are in any way assisted by acquired modifications, &c., during periods in which, without such assistance, they would be eliminated—until (2) the appearance and selection of congenital variations which can get along without such assistance [pp. 113–114].

In the words of Osborn: "Individual or acquired modifications in new circumstances are an important feature of the adult structure of every animal. Some congenital variations may coincide with such modifications, others may not. The gradual selection of those which coincide (coincident

[1] Op. cit., pp. 101–102. Insertions in [ ] are our own.

[2] Osborn, H. F.: Abstr. [A Mode of Evolution requiring neither Natural Selection nor the Inheritance of Acquired Characters.] *Trans. N. Y. Acad. Sci.,* vol. XV, Mar. 9 and Apr. 13, 1896, pp. 141–142, 148. Organic Selection, *Science,* N. S., vol. VI, No. 146, October 15, 1897, pp. 583–587. The Limits of Organic Selection, *Amer. Naturalist,* vol. XXXI, No. 371, Nov. 1893, pp. 944–951. Modification and Variation, and the Limits of Organic Selection: A Joint Discussion with Professor Edward B. Poulton, of Oxford University. *Abstr. Proc. Amer. Assoc. Adv. Sci.,* vol. XLVI, June, 1898 (Meeting of August, 1897), p. 239. Coincident Evolution through Rectigradations (third paper), *Science,* N. S., vol. XXVII, No. 697, May 8, 1908, pp. 749–752.

[3] Baldwin, J. Mark, Organic (or Indirect) Selection. *Dictionary of Philosophy and Psychology,* vol. II, The Macmillan Company, 1902, pp. 213–214.

variations) may constitute an apparent inheritance of acquired modifications"; and of Lloyd Morgan (*Habit and Instinct*, 315): "Though there is no transmission of modifications due to individual plasticity, yet these modifications afford the conditions under which variations of like nature are afforded an opportunity of occurring and of making themselves felt in race progress."

Another phase of the possible results of the action of "coincident selection" is illustrated in what Baldwin has to say regarding orthoplasy.[1]

ORTHOPLASY (Gr. *ὀρθός*, straight, + *πλάσις*, a fold): Ger. *orthoplasie;* Fr. *orthoplasie;* Ital. *ortoplasia.* Determinate or definitely directed evolution under the laws of natural and organic selection (see those terms). [Diagram.] . . . This term has been suggested and adopted by the advocates [*i. e.*, Baldwin] of the theory of organic or indirect selection as opposed to Orthogenesis (q. v.), the latter having a vitalistic meaning, and implying Lamarckian heredity. Orthoplasy, on the contrary, emphasizes natural selection working upon variations in many cases screened and fostered by the presence of individual modifications. Cf. Convergence (in biology), *ad fin.*

The successive formulæ of the inseparable factors corresponding with the hypothesis of "coincident selection" are as follows:

H O E^1 S = first, or environmental phase of initiation, in which change of habit is rendered necessary.

H O^2 E^1 S = in which a change of environment is followed by a change in ontogeny, resulting from the formation of a new habit.

H^3 O^2 E^1 S = fourth phase in which hereditary predispositions arise in heredity or saltations which happen to coincide with the modifications introduced by the changes of habit and ontogeny. This is the "coincident variation" of Morgan.

H^3 O^2 E^1 S^4 = final phase in which selection acts upon all cases in which heredity coincides with ontogeny.

The following citation is from the original statement[2] of the hypothesis of coincident selection by Osborn in 1896:—

". . . the adult form of any organism is an exponent of the stirp, or constitution + the environment. If the environment is normal the adult will be normal, but if the environment (which includes all the atmospheric, chemical, nutritive, motor and psychical circumstances under which the animal is reared) were to change, the adult would change correspondingly; and these changes would be so profound that in many cases it would appear as if the constitution, or stirp, had also changed. Illustrations might be given of changes of the most profound character induced by changes in either of the above factors of environment, and in the case of the motor factor or animal motion the habits of the animal would, in the course of a life time, profoundly modify its structure. For example, if the human infant were brought up in the branches of a tree as an arboreal type instead of as a terrestrial, bi-pedal type, there is little doubt that some of the well-known early adaptations to arboreal habit (such as the turning in of the soles of the feet, and the grasping of the hands) might be retained and cultivated; thus a profoundly different type of man would be produced. Similar changes in the action of environment are constantly in progress in nature, since there is no doubt that the changes of environment and the habits which it so brings about far outstrip all changes in constitution. This fact, which has not been sufficiently emphasized before, offers an explanation of the evidence advanced by Cope and other writers that change in the forms of the skeletons of the vertebrates first appears in ontogeny and subsequently in phylogeny. During the enormously long period of time in which habits induce ontogenic variations it is possible for natural selection to work very slowly and gradually upon predispositions to useful correlated variations, and thus what are primarily *ontogenic variations* become slowly apparent as *phylogenic variations* or congenital characters of the race. Man, for instance, has been upon the earth perhaps seventy thousand years; natural selection has been slowly operating upon certain of these predispositions, but has not yet eliminated those traces of the human arboreal habits, nor completely adapted the human frame to the upright position. This is as much an expression of habit and ontogenic variation as it is a constitutional character" (pp. 141–142).

[1] Baldwin J. Mark, Orthoplasy. *Dictionary of Philosophy and Psychology*, vol. II, The Macmillan Company, 1902, p. 251.

[2] Abstr. [A Mode of Evolution requiring neither Natural Selection nor the Inheritance of Acquired Characters.] *Trans. N. Y. Acad. Sci.*, vol. XV, Mar. 9 and Apr. 13, 1896, pp. 141–142, 148.

4. Initiation and Genesis in Heredity.

We must again (see p. 291) make clear the comprehensive nature of heredity, in relation to our law of the four inseparable factors. As one of the four factors heredity includes the forces underlying all that is heritable, whether resemblance or variation, whether patent or latent, dominant or recessive, ancestral or new; forces which are inseparable from those of environment and ontogeny. Thus the term is employed in a more comprehensive sense than by some other recent authors. For example, Castle in his work *Heredity in Relation to Evolution and Animal Breeding* (1911) attaches the following meaning to heredity: "By heredity, then, we mean organic resemblance based on descent." Another author, Jennings, observes: "An organism's heredity is its method of responding to the environmental conditions."

Far closer analysis as regards the problems of initiation and genesis is demanded in heredity than in ontogeny. In the biology of the past there were a number of loosely accepted principles which the modern exact study of genetics is compelling us to examine far more closely; this demand for rigid analysis is one of the greatest services rendered by the recent students of genetics, inspired by Mendel.

There are five great classes of problems awaiting solution in heredity:

1. What are the relations between *initiation* in environment and ontogeny and the *genesis* of new characters in heredity?

2. Is there any real genesis of new characters in heredity without initiation by environment or ontogeny?

3. Does the genesis of new characters in heredity conform or show a likeness to the antecedent initiation of environment or of ontogeny, or is it independent of it?

4. Is genesis in heredity exclusively a continuous[1] or discontinuous process, or do we observe both modes of continuity and discontinuity?

5. Is genesis in heredity a process ordered by law or is law established indirectly through elimination of the lawless (inadaptive) and selection of the lawful (adaptive) out of an indefinite number of trials?

It is not the purpose of this contribution to attempt to discuss any of these five classes of problems or to review the various answers which are being given by investigators in different fields at the present time.

The kinds of characters which require analysis as regards initiation and genesis have been fully enumerated in a preceding section, p. 300.

5. Genesis as Observed in Palæontology.

The author's opinions, which are based on prolonged palæontological observations but which await verification, are the following:[2]

[1] Osborn, H. F.: The Continuous Origin of Certain Unit Characters as Observed by a Paleontologist, Harvey Lecture, *Amer. Naturalist*, vol. XLVI, No. 544, Apr., 1912, pp. 185–206, No. 545, May, 1912, pp. 249–278.

[2] Osborn, H. F.: The Palæontological Evidence for the Transmission of Acquired Characters, *Amer. Naturalist*, vol. XXIII, No. 271, July, 1889, pp. 561–566. *Proc. Amer. Assoc. Adv. Sci.*, vol.

1. That the genesis of many new characters occurs through some internal action in heredity without the initiation or coincident appearance of similar characters in ontogeny.

2. That such genesis of new characters in heredity occurs not spontaneously nor irrespective of other conditions, nor from the purely internal mechanical forces of heredity, but through some entirely unknown and at the present time inconceivable relation between the forces of heredity and those of ontogeny and environment.

3. That such characters in heredity arise determinately, definitely, but by extremely slow stages, or continuously.

4. That animals of different but remotely related lines of descent show degrees of similarity in the genesis of such characters which correspond in closeness with the degrees of taxonomic relationship. This is the law of "potential homology."[1]

5. The degrees of taxonomic relationship also affect to a certain extent the *time* of the genesis of new characters as well as the *rate of development* of new characters.

6. That since such genesis of new characters springs from the internal forces of heredity, the continuous or discontinuous appearance of a new character may be simply the expression of the same law or operating at a different rate.

The principle of *potential homology* is based upon the observation that animals of similar kinship do not continuously evolve in certain directions but merely transmit a similar potentiality in the genesis of new characters. This hereditary potential both renders possible the occurrence of certain characters and conditions or limits or forms these characters when they do occur. This is not an internal perfecting tendency in heredity through which animals reach a certain condition through the operation of an internal mechanical law of development, but a potentiality in heredity which under the law of the four inseparable factors

38, July, 1890 (meeting, Toronto, Aug., 1889), pp. 273–276. Rept. Brit. Assoc. Adv. Sci., Newcastle-upon-Tyne (meeting of Sept., 1889), London, 1890. The Palæontological Evidence for the Transmission of Acquired Characters, *Nature*, vol. XLI, Jan., 1890, pp. 227–228. Certain Principles of Progressively Adaptive Variation Observed in Fossil Series, *Rept. Brit. Assoc. Adv. Sci.*, 1894, p. 693 (title). *Nature*, vol. 50, No. 1296, Aug. 30, 1894, p. 435. The Hereditary Mechanism and the Search for the Unknown Factors of Evolution, *Biol. Lect. Marine Biol. Lab.*, 1894, Ginn & Co., Boston, 1895. *Amer. Naturalist*, vol. XXIX, No. 341, May, 1895, pp. 418–439. The Biological Problems of To-day: Palæontological Problems (Discussion before the annual meeting of the American Society of Naturalists). *Science*, N. S., vol. VII, No. 162, Feb. 4, 1898, pp. 145–147. Evolution as it Appears to the Paleontologist. Address before the Seventh International Zoological Congress, Section of Palæozoology, Boston, Aug. 1907. *Science*, N. S., vol. XXVI, No. 674, Nov. 29, 1907, pp. 744–749. *Proc. Seventh International Zool. Congr.*, Boston Meeting, Aug. 19–24, 1907, Cambridge, Mass., 1912, pp. 733–739. Darwin and Palæontology. One of the Addresses in Fifty Years of Darwinism. 8vo. Henry Holt & Co., New York, April, 1909, pp. 209–250. To the Philosophic Zoologist, *Science*, N. S., vol. XXIX, No. 753, June 4, 1909, pp. 895–896.

[1] Osborn, H. F., Homoplasy as a Law of Latent or Potential Homology, *Amer. Naturalist*, vol. XXXVI, Apr., 1902, pp. 259–271. Evolution of Mammalian Molar Teeth to and from the Triangular Type. 8vo. Macmillan Co., New York and London, 1907. See Chap. X.

operates in a manner adapted to new conditions and through the interaction of forces which are entirely unknown and incomprehensible to us.

The formula of both initiation and genesis in heredity will be as follows:

$$H^1 \times O \times E \times S.$$

The above will be the formula of an internal perfecting principle operating independently of initiation through the action of environment or of ontogeny. In our opinion there is no evidence for such an internal perfecting principle.

SUMMARY.

Investigation and experiment may proceed to test two working hypotheses: *first*, that while inseparable from the others each factor may under certain conditions become an initiative or leading factor; *second*, that in complex organisms one factor may be initiative in one group of characters while another factor may at the same time be initiative in another group of characters, the inseparable action bringing about a continuously harmonious result.

The following general summary may be made as to our conception of the interoperation of the several factors:

1. In all conditions of life the four factors work together continuously like the forces of four magnetic fields although the readjustments are so infinite that analogy with any physical phenomenon such as the above cannot express the interaction.

2. Each of these factors has its specific sphere of action in which the modes of externally observed phenomena are apparently supreme; for example, we recognize the supreme action of selection and of elimination in certain cases, in other cases the supreme action of the direct influences of environment or the supreme action on ontogenic modifications of structure caused by certain habits, or the still more profound and permanent changes which reflect disturbances in heredity.

3. Under certain natural as well as artificial conditions a supreme factor may arise operating more strongly than the others, or two factors may simultaneously become supreme and take the initiative in instituting a change. Thus there are changes of the *first order* (*i. e.*, initiative), and changes of the *second order* (*i. e.*, those which follow or are coordinated with the former; compare Crampton). Alter one factor ever so slightly and the entire balance between the four may be disturbed, a disturbance comparable to the disturbance in the balance of nature.

4. The changes which are initiated in environment and ontogeny sooner or later become reflected or expressed in heredity.

5. The causal relation, if such exists, between the real genesis of characters in heredity and the factors of ontogeny and environment still remains as the chief field of investigation in biology.

APPENDIX.

Note on the Quantitative Representation of the Factors of Evolution.

By William K. Gregory.

Let F represent the average condition of a given part in the ancestral species (may refer to area, volume, degree of saturation of color, strength of muscle or any characteristic capable of quantitative determination).

Let F_n represent the average condition of the same characteristic in a derived species or descendant of F.

Then $F_n - F$ is the measure of evolution of the part, and $100(F_n - F)/F$ is the percentage increment of F_n over F.

Hence $F_n = F + (P/100)F$, where $P/100$ represents the total percentage increment of F_n over F.

Suppose that this total percentage increment is made up of the following partial increments:

H (heredity), that part of the total percentage increment which may be ascribed hypothetically to an orthogenetic or germinal tendency to increase, diminish or maintain the original condition.

S (selection), that part of the total percentage increment which may be ascribed hypothetically to the selective effect of environment upon a germinally unstable race.

O (ontogeny), all those parts of the total percentage increment which may be ascribed hypothetically to metabolic changes arising in the soma, evoked either by use and disuse or by physiological correlation during individual development.

E (environment), that part of the total percentage increment which may be ascribed hypothetically to the action of environment. (See page 301.)

Substituting these symbols in the formula $F_n = F + (P/100)F$ we have

$$F_n = F + \left(\frac{H + S + O + E}{100}\right)F,$$

whence

$$H + S + O + E = 100\left(\frac{F_n - F}{F}\right).$$

In palæontological researches one is frequently able to find the numerical value of $(F_n - F)/F$ and hence to obtain an exact measure of $H + S + O + E$ taken together.

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The Phylogenetic Value of Color Characters in Birds

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PHILADELPHIA
1912

THE PHYLOGENETIC VALUE OF COLOR CHARACTERS IN BIRDS.

By Witmer Stone, A.M.

The question of the origin and significance of color patterns and color combinations in the plumage of birds is far from being satisfactorily explained. The correlation between dark suffused tints and a dark humid environment; and between light, bleached tones and an open, desert environment is familiar, even though opinions may differ as to the part played in their production by light and moisture on the one hand and protective resemblance on the other.[1] Further cases of alleged concealing or protective coloration have frequently been cited especially among the *Limicolæ* but certain recent attempts to account for practically all types of coloration on these grounds are so extravagant as to make one seriously question the whole theory of protective color patterns.[2]

Were all color patterns the result of the concealment or protection that they afford to the animal possessing them, there would certainly be little chance for the resemblances in general type of coloration which we often find in species of the same genus or same family, living in different countries and in different environments.

Furthermore in the light and dark forms characteristic respectively of desert or humid areas we are able to ascribe only the relative intensity of the shades of color to the effect of moisture or sunlight, not the fundamental color pattern or primary tints, which are obviously due to other causes.

In certain cases too the intensity of color and to some extent the color pattern itself have been found to vary in island areas which so far as can be determined have precisely the same environment. The most closely related forms so far as coloration is concerned are often the most remote geographically. Mr. G. S. Miller, Jr., has described such a condition among the mouse deer of the islands of the Rhio-Linga Archipelago.[3] In such instances there seem to be certain inherited tendencies which develop along lines of least resistance as it were, in different combination and varying intensity in each isolated colony, the resultant forms converging or diverging without regard to geographic relationship.

All these cases, however, relate to color forms differing but slightly from one another and the brilliant color combinations especially frequent among tropical birds are hardly to be explained by any theory of concealment or protection, nor have they been satisfactorily explained in any other way. The problem is

[1] Cf. Beebe, Geographic Variation in Birds with Especial Reference to the Effects of Humidity. *Zoologica*, I, No. 1, 1907, pp. 1–41 (N. Y. Zool. Soc. Publ.).

[2] Cf. G. H. and A. H. Thayer, Concealing Coloration in the Animal Kingdom, 1900; also Barbour and Phillips, *The Auk*, 1911, pp. 179–188, and Roosevelt, *Bull. Amer. Mus. Nat. Hist.*, XXX, 1911, pp. 119–231.

[3] *Proc. U. S. Nat. Mus.*, XXXVII, pp. 1–9, Sept., 1909.

no doubt a complicated one, into which different elements enter in varying proportions. The striking contrasts and resemblances, however, with which we meet not only in closely allied groups but also in those obviously not intimately related, offer an attractive field for investigation and one which is likely to lead to important results.

I have been interested in considering especially one phase of this question, namely: how far coloration may be used in various groups of birds as a clue to the phylogeny of the species. In certain genera the dominant color is an obvious and excellent group character, as for instance red in the genus *Cardinalis* or green in the genus *Chloropsis*. So too, similar color patterns are found to run through all, or nearly all, species of certain large groups, as for instance the metallic blue or green speculum in the ducks, or the blue-and-black wing patch in the true jays; while in other groups certain colors are conspicuous by their absence, as the lack of red among the jays or green among the thrushes.

Reverting to *Cardinalis*, we find the allied genus *Pyrrhuloxia* exhibiting the same heavy bill and conspicuous red coloration but differing clearly in the shape of the bill and in the great admixture of the gray in the plumage. Here we see differentiation both in structure and coloration by which *Cardinalis* and *Pyrrhuloxia* have departed from a common ancestral type. In many cases, however, differentiation has taken place in only one set of characters. For instance in the genus *Merops* we have a green and yellow color type, a red and green type and a green and chestnut type, but none of the species show any corresponding structural differences. In the genus *Tyrannus* also we have gray and white breasted species and others with sulphur yellow breasts, but no parallel variation in the proportions of the bill or other structural characters. On the other hand we have groups like *Geospiza* of the Galapagos Islands, where all manner of variation in the size and proportions of the bill have taken place while the coloration of the plumage remains the same throughout. Attempts have been made to divide the species into several genera according to bill structure but such an unbroken series of forms exists connecting one extreme with the other that it seems well-nigh impossible. A still more remarkable illustration is seen in the East Indian cuckoos of the essentially monotypic genera *Dryococcyx* from Celebes, *Rhinococcyx* from Java, and *Urococcyx* from Sumatra and the Malay peninsula. These birds differ strikingly in the location and character of the nasal opening which has resulted in establishing them in three separate genera, yet their coloration is so exactly similar that they are with difficulty distinguished in the hand without examining the bill. (Pl. XXVII, figs. 1, 3, and 6).

The same differentiation in bill structure is found sometimes in two forms inhabiting the same region as in the Chilian parrots *Enicognathus leptorhynchus* and *Micrositta ce ferrugineus*, both of which are green, with red tails and red on the lores, forehead and abdomen, but which differ materially in the structure of the upper mandible (Pl. XXVII, figs. 7 and 10).

In such cases it seems obvious that differentiation in bill structure has taken

place without change in color pattern. Were there as many intermediate forms among these cuckoos as there are in the genus *Geospiza*, they would of necessity be retained in one genus and they might still be, with as much right as are the three color types in the genus *Merops*, if we were accustomed to regard modification of bill and variation of color pattern as characters of equal importance. As a matter of fact, however, ornithologists do not regard style of coloration as a generic character unless it emphasizes some tangible structural character of bill or feet or some difference in the relative proportions of remiges or rectrices. Color plays a most important part in the differentiation of species and subspecies and since we must admit that the genera of birds are groups of very much lower rank than genera in other classes of the animal kingdom there seems no reason why more weight should not be given to color characters in the study of generic differences and phylogeny. Furthermore the tendency is constantly toward a still greater refinement of genera, differences are being magnified and resemblances neglected, and search is always being made for slight so-called structural differences and not for characters which will bind several genera together into one genetic phylum. It seems high time that more attention were given to this phase of the study and I am inclined to think that in this connection a careful study of coloration will aid materially; giving us not only an idea of the interrelationship of the species of a genus but also a clue to the phylogeny of the genera.

It seems probable also that certain species for which a distinct genus has been established upon trivial characters, such as the comparative length of the tail feathers, are really more closely allied to similarly colored species of an allied genus, than they are to the differently colored species with which they are arbitrarily associated.

Such a case we find in the *Meropidae*. The family comprises some forty-one species or subspecies. Three of them stand distinct from the rest both as regards coloration and structure—*Meropogon forsteni* and the two species of *Nyctiornis*. The other thirty-eight are closely related to one another and while they exhibit remarkable diversity of coloration, they present very slight structural differences. In the attempts to subdivide the group the only character that systematists have been able to find is the relative length of the tail feathers. In the genus *Dicrocercus* the tail is deeply forked, in the fifteen species of *Melittophagus* it is square, while in the twenty-one species of *Merops* the central pair of rectrices are narrowed and project beyond the others.

Dicrocercus is essentially monotypic and confined to Africa. *Melittophagus* is also African with the exception of two species which occur respectively in Java and in the Indo-Malay region. *Merops* on the other hand occurs throughout Africa as well as in southern Europe, Arabia, the Indo-Malay region, and Australia. In studying the coloration of these genera we find that *Dicrocercus* closely approaches one of the African groups while the two other genera resolve themselves into several groups. The red-throated species of *Melittophagus* are

exclusively African and so also are the red-breasted species of *Merops*. In other words no species with red in the plumage occur outside of Africa. Six of the African species of *Melittophagus* form a well-marked group, with green backs, yellow throats, and a distinct black or blue breast band. (Pl. XXVII, fig. 5.) In Java and the Indo-Malay region occur respectively *M. leschenaulti* and *M. swinhoii*, which resemble the African group in the plumage of the lower surface, but differ above in having the anterior portion (head to interscapulum) chestnut color, and the rump blue. (Pl. XXVII, fig. 4.) No *Melittophagus* occurs in Sumatra or Borneo but in these islands as well as in parts of the Malay peninsula and north to southern China, occurs a *Merops* with precisely the same distribution of chestnut above but the blue of the rump extending to the tail. Below, however, the throat is blue and there is no breast band. (Pl. XXVII, fig. 2.) A closely allied species inhabits the Philippines to the east while the European *Merops apiaster*, whose distribution touches the ranges of these species on the west, is the only other chestnut-backed species of *Meropidæ*.

It seems to me that this close correspondence of certain types of coloration to certain geographic areas is significant, and I should much rather regard the elongation of the central tail feathers as a tendency likely to crop out at any time and place than to consider that the two types of tail structure developed first and that several types of color combinations were later evolved in each group in almost exact parallelism. We might argue that the environment had something to do with the question, resulting in red-breasted or red-throated forms of each genus in Africa and chestnut-backed forms in the Indo-Malay and European countries, but unfortunately for such a theory other species inhabit these regions which have totally different color patterns. Furthermore in West Africa we find side by side several of the most aberrant species of the family so far as color is concerned, differing widely from one another both in color pattern and colors.

In arguing for phylogenetic significance in coloration I do not mean to say that we can divide a family like the *Meropidæ* into definite "color genera" nor can we trace exact lines of descent for all the species. Naturally many connecting links have become quite extinct so that species like some of those from West Africa have scarcely a single color character in common with any other species of the family. In other groups we find numerous family color characters in all sorts of combination, now one of them being suppressed, now another.

It does, however, seem to me that color patterns can be used to advantage in testing the real value of so-called structural characters. Where a different color pattern is combined with a difference in structure of the bill as in *Cardinalis* and *Pyrrhuloxia*, and especially where, as in this case, the distribution of the species of each genus is continuous, the evidence that we have a natural, phylogenetic division of species into two groups is obvious. On the other hand where we find the same color characters occurring in two genera which have been separated upon a trivial and variable character such as the elongation of the central rectrices, the inference is that the genera are artificial and not phylo-

genetic, and that the species are better left in one genus, associated according to color characters even though we confess an inability to arrange them all in definite color groups.

The *Alcedinidæ* furnish an exceedingly interesting series of color types, with comparatively little structural differentiation. The widespread genus *Ceryle* with a generally admitted distinctive form of bill, exhibits several quite different types of coloration in Africa, India, Japan, and America respectively, but all of them different from anything found among the remaining species of the family.

Other so-called genera are much less satisfactory. *Alcyone* and *Ceyx* are established upon the fact of their having but three toes instead of four. The species of *Alcyone* ranging from northern Australia to New Guinea and adjacent islands have the upper parts plain blue above, neither banded nor spotted. *Ceyx* on the other hand presents several types of coloration, many species being tawny above with a violet wash and little or no blue, while others are largely black or blue above. *C. cyanipectus* and its allies would unquestionably be regarded as members of the genus *Alcedo* were it not for the reduction in the number of toes. Indeed *C. cyanipectus* is a perfect counterpart in coloration and bill structure of *Alcedo moluccana*. In the same way a little tawny kingfisher of Madagascar, a typical *Ceyx* in coloration, is placed in the differently colored African genus *Ispidina* on account of the presence of the fourth toe. (Pl. XXVII, fig. 9.) No authors seem to claim any close relationship between *Alcyone* and *Ceyx* by virtue of the suppression of one of the toes and the character does not seem to be a very important one, therefore I see no reason why *Ceyx cyanipectus* should not be regarded as a three-toed offshoot of the *Alcedo* stock or that *Ispidina madagascariensis* (Pl. XXVII, fig. 9) may not be quite as closely related phylogenetically to *Ceyx* (Pl. XXVII, fig. 8) as to *Ispidina*. The species of the genus *Halcyon* present such slight structural variations that efforts at generic subdivision have proven futile. It is the grand residuum after a few well marked groups have been removed; such as *Dacelo*, *Todiramphus*, *Syma*, *Tanysiptera*, etc. These seem to be perfectly natural associations of species but even so, the coloration of some of them is so strikingly like certain species of *Halcyon* that one wonders to which genus the latter are more closely allied. *Dacelo cervina* for example is a perfect duplicate of *Halcyon chelicuti* and *Todiramphus recurvirostris* of *H. sanctus* while species of *Pelargopsis* follow so closely the pattern and tints of *H. cinnamomeus* that one wonders after all whether the resemblance in bill structure between *Pelargopsis* and *Ceryle* is not merely parallelism, and whether the former is not more nearly allied to *Halcyon*.

It is not the aim of this paper to propose any changes in classification or nomenclature suggested by the examples which have been cited. They are presented simply as suggestions.

It is quite possible that color resemblances do not necessarily denote close

phylogenetic relationships after all, but that each family or other group possesses a certain number of color tendencies which are liable to crop out or be repressed at different parts of the "family tree," as for instance the uniform tawny coloration which has already been referred to as occurring in *Ceyx* and also in one species of *Ispidina*, and which is found also to some extent in *Pelargopsis* and *Syma*. Then there is the tendency to blue coloration above which is well developed in many species and which is perhaps mingled with the tawny color tendency in certain species of *Ceyx* above referred to. Each family or lesser group seems to have a limited number of colors which in various combinations and in varying shades go to make up the coloration of the great majority of its species. Other colors come in, in the case of outlying species which approach other families, and perhaps inherit certain color tendencies common to them. The curious brown and white barred plumage of the female of *Carcineutes pulchellus*, for instance, is unique among kingfishers but recalls certain species of *Bucconidæ*.

So also there are certain details of pattern which are characteristic of certain families or genera and are present in the majority of the species, as the black auricular patch and crescentic breast band in *Meropidæ*, and the red nuchal crescent in woodpeckers.

Sometimes both colors and pattern are reproduced in remarkable parallelism in remote parts of the range of a family as, for instance, *Helmitherus vermivorus* of the Eastern United States, and *Basileuterus auricularis* of Western Ecuador, members of the family *Mniotiltidæ*, both of which possess the same dull olive tone, and the same striped cap.

In matters of pattern there seems to be a deeper problem involved, *i. e.*, the determination of the cause governing the appearance of a differently colored patch on corresponding parts of the plumage of birds belonging to wholly different groups. For instance the crescentic breast patch in *Colaptes* among the woodpeckers, *Sturnella* of the *Icteridæ*, *Cyanocitta* in *Corvidæ*, etc.; or the presence of a mystacial stripe, a superciliary stripe, a light rump patch, light wing bars, etc.

In fact if a bird exhibits a bright or contrasting patch of color it is, in the vast majority of cases, found on one of several definite portions of the plumage, as the crown, the throat, the bend of the wing, the rump, etc.

There is much important data in this field to be gathered and compared.

The probably purely accidental combination of similar patterns and similar colors results in certain remarkable cases of parallelism in birds in no way related, as the red-shouldered black weaver bird of Africa, *Diatropura progne*, and the red-winged blackbird, *Agelaius phœniceus*, of North America; the African pipit, *Macronyx croceus*, and the North American meadowlark, *Sturnella magna*.

The point I wish to emphasize is the need of a more thorough study of the coloration of birds with the search directed to resemblances rather than to minute differences. The correlation of certain patterns and combinations of color with groups showing real structural differences, the study of coloration in

connection with geographical distribution and especially the study of the juvenal plumages of brilliant tropical birds will result in the accumulation of data which will ultimately prove of the greatest value in throwing light upon the true relationship of the various groups of birds and possibly upon the origin and meaning of the colors themselves.

EXPLANATION OF PLATE XXVII.

Illustrating similarity of coloration in species currently placed in different genera.

FIG. 1. *Urococcyx erythrognathus* (Hartl.).
FIG. 2. *Merops bicolor* Bodd.
FIG. 3. *Rhinococcyx curvirostris* (Shaw and Nodder).
FIG. 4. *Melittophagus swinhoii* (Hume).
FIG. 5. *Melittophagus cyanostictus* Cab.
FIG. 6. *Dryococcyx harringtoni* Sharpe.
FIG. 7. *Enicognathus leptorhynchus* (King).
FIG. 8. *Ceyx dillwynni* Sharpe.
FIG. 9. *Ispidina madagascariensis* (Linn.).
FIG. 10. *Microsittace ferrugineus* (Müll.).

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Further Experiments with Mutations in Eye-Color of Drosophila: The Loss of the Orange Factor

BY

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PHILADELPHIA
1912

FURTHER EXPERIMENTS WITH MUTATIONS IN EYE-COLOR OF DROSOPHILA: THE LOSS OF THE ORANGE FACTOR.

THOMAS HUNT MORGAN, PH.D.

In previous papers (1910–1911) dealing with the inheritance of eye color in mutants of the fruit fly *Drosophila ampelophila*, I have shown that the red color of the eye of the wild fly is due to the presence of at least four factors. These factors are vermilion (*V*),[1] pink (*P*), and orange (*O*), and a color producer (*C*). The red eye has all four factors present, and may be represented by the formula *VPOC*. The vermilion eye has *V* and *O* present, but has lost the pink factor. It is designated by *VpOC*. The pink eye has *V* absent, and is therefore *vPOC*. The orange eye contains neither *V* nor *P*, and is therefore *vpOC*. Of these factors *P* and *C* have been found to be sex-linked; that is, they follow the factor that in duplex produces the female sex, and, since the factor for femaleness goes with the sex-chromosome, the factors *P* and *C* may be said to lie in this chromosome. When present they are represented in duplex in the female and simplex in the male. The full formulæ therefore for the eye-colors, and the sex-factor are as follows:

Red eye	♀ *VPOCXVPOCX*	Plate XXVIII, fig. 1
Red eye	♂ *VPOCXVpoc*	
Vermilion eye	♀ *VpOCXVpOCX*	Plate XXVIII, fig. 2
Vermilion eye	♂ *VpOCXVpoc*	
Pink eye	♀ *vPOCXvPOCX*	Plate XXVIII, fig. 3
Pink eye	♂ *vPOCXvpoc*	
Orange eye	♀ *vpOCXvpOCX*	Plate XXVIII, fig. 4
Orange eye	♂ *vpOCXvpoc*	

In my former papers the distribution of the orange factor could not be given, because the factor *O* had never been lost. Whether, for instance, it is sex-linked, in the sense that the factor *P* is sex-linked, or whether it is present in all the eggs and sperm, as is the factor *V* when present, was not apparent; for, the the results would be the same so long as all of the eggs and the female producing sperm contain the factor for orange.

But later a mutant appeared that had lost the factor for orange, as suitable matings made clear. It was then discovered that the factor, *O*, is also sex-linked; and in the complete formulæ, given above, the factor *O* is omitted from all the male-producing sperm. Its absence is indicated by small *o*.

[1] In my former papers the factor was designated by *R*.

One of the first mutants that appeared had white eyes, *i. e.*, eyes without any color except in so far as white may be called a color. In fact the white eye is not a transparent eye but is distinctly white. This effect might be due to interference of light waves, as in white snow flakes, or it might be due to white pigment. It is difficult to state positively which of these views is correct for the white eye, but a white pigment is present, and I am inclined to attribute the whiteness, in part, to this condition.

The white eye is due to the loss of a color producer *C*. Since white-eyed flies may belong to any one of the eye colors given above, *i. e.*, by suitable combinations it may be shown that there are white-eyed flies that carry the determiners for vermilion, others for pink. The discovery of a new mutant lacking orange has shown, however, that when the factor *C* is lost the factor for orange is also lost. These two factors appear closely linked, and generally go together. The evidence for this interpretation will be given later. The white-eyed series is represented by the following formulæ:

(Red) White	♀ *VPocXVPocX*	Fig. 6.
(Red) White	♂ *VPocXVpoc*	
(Vermilion) White	♀ *VpocXVpocX*	
(Vermilion) White	♂ *VpocXVpoc*	
(Pink) White	♀ *vPocXvPocX*	
(Pink) White	♂ *vPocXvpoc*	
(Orange) White	♀ *vpocXvpocX*	
(Orange) White	♂ *vpocXvpoc*	

Before taking up the experiments dealing with the new mutant that lacks orange, I wish first to consider certain cases that were not clear from the earlier studies. Their reexamination has furnished striking proof of the correctness of the interpretation that was there followed.

The Red-Pink Ratio.

In the crosses between red-eyed and pink-eyed flies reported in my former paper, the Pinks ran far behind their schedules in the F_2 generation. The expectation both for females and males is three Reds to one Pink. The actual F_2 ratio in one cross was 20 to 1; and in the reciprocal cross the F_2 ratio was 5 to 1. The striking difference between the realized and the expected ratios could only be attributed to the viability of the pink flies. In order to test this combination once more I asked one of my students, Mr. Joseph Liff, to repeat the experiment; and at the same time to make back crosses, and counter crosses; as well as to take counts of individual pairs of the flies. His results are as follows:

$$R\,♀ \text{ by } P\,♂ = \begin{matrix} R\,♀ \\ R\,♂ \end{matrix} = \begin{cases} \text{Red } ♀ & 420 \\ \text{Red } ♂ & 413 \\ \text{Pink } ♀ & 104 \\ \text{Pink } ♂ & 94 \end{cases}$$

RECORDS BY SEPARATE BOTTLES *A*, *B*, *C*.

Red ♀ × *Pink* ♂ → *in* F_2.

Bottle.	♀		♂		Total.	Proportion of Red to Pink.	Total.	
	Red.	Pink.	Red.	Pink.			Red.	Pink.
A	162	51	156	43	412	3.3 : 1	318	94
B	80	14	60	20	174	4.1 : 1	140	34
C	178	39	197	31	445	5.3 : 1	375	70
Total	420	104	413	94	1031		833	198

The expectation is 3 Red to one Pink. The average result is 4.2 to 1. The three bottles gave different ratios; one, *A*, giving 3.3 to 1.

The converse cross is as follows:

$$P\ ♀ \text{ by } R\ ♂ = \begin{matrix}\text{Red } ♀ \\ \text{Red } ♂\end{matrix} = \begin{cases}\text{Red } ♀\ 733 \\ \text{Red } ♂\ 589 \\ \text{Pink } ♀\ 189 \\ \text{Pink } ♂\ 140\end{cases}$$

RECORDS BY SEPARATE BOTTLES *A*, *B*, *C*.

Bottle.	♀		♂		Total.	Proportion of Red to Pink.	Total.	
	Red.	Pink.	Red.	Pink.			Red.	Pink.
A	268	62	273	62	665	4.3 : 1	541	124
B	141	51	58	12	262	3.2 : 1	199	63
C	324	76	258	66	718	4.3 : 1	582	136
Total	733	189	589	140	1,645		1,322	323

Here also the expectation is 3 to 1. The average result is 4 to 1. One culture-bottle, *B*, gave, however, 3.2 to 1.

In order to examine the problem more closely, the offspring of F_1 pairs were recorded separately. The next table gives the data for one of the crosses.

F_1 Pairs out of Red ♀ × *Pink* ♂.

Bottle.	♀		♂		Total.	Proportion of Red : Pink.
	Red.	Pink.	Red.	Pink.		
I	45	10	42	8	105	5 : 1–
II	79	20	69	13	181	4.5 : 1
III	60	9	59	18	146	4.4 : 1
IV	21	2	18	4	45	6.5 : 1
V	17	5	23	8	53	3 : 1
VI	39	8	34	6	87	5.2 : 1
VII	82	21	57	29	189	2.8 : 1
VIII	84	21	65	22	192	3.5 : 1
IX	16	2	9	7	34	3 : 1+
X	50	13	34	17	114	2.8 : 1
XI	55	20	42	17	134	2.6 : 1
XII	32	7	30	11	80	3.5 : 1
XIII	32	4	24	8	68	4.6 : 1
XIV	37	19	62	18	136	2.5 : 1
Total	629	161	568	186		

The expectation is 3 Reds to 1 Pink. The results vary from 6.5 to 1 to 2.5 to 1, the sum total giving a ratio of 3.5 to 1, which closely approximates to the results of the mass culture.

The reciprocal cross, recorded in pairs, is given in the next table. The ratio ranges from 5.8 to 1, to 1.8 to 1. The average proportion of Red to Pink is 3.84 to 1.

F_1 Pairs out of Pink ♀ × Red ♂.

Bottle.	♀		♂		Total.		Grand Total.	Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.		
I	57	17	64	19	121	36	157	3.4 : 1
II	62	15	54	21	116	36	152	3.2 : 1
III	69	17	75	17	144	34	178	4.2 : 1
IV	25	7	39	4	64	11	75	5.8 : 1
V	58	13	41	20	99	33	132	3 : 1
VI	41	14	32	12	73	26	99	2.8 : 1
VII	107	29	72	42	179	71	250	2.5 : 1
VIII	83	14	71	25	154	39	193	4 : 1
IX	49	14	59	15	108	29	137	3.7 : 1
X	10	2	14	4	24	6	30	4 : 1
XI	42	17	45	10	87	27	114	3.2 : 1
XII	21	15	30	14	51	29	80	1.8 : 1
XIII	51	10	38	7	89	17	106	5.2 : 1
XIV	83	17	80	16	163	33	196	5 : 1
XV	94	19	84	23	178	42	220	4.2 : 1
XVI	72	27	54	15	126	42	168	3.2 : 1
XVII	50	10	29	5	79	15	94	5.3 : 1
XVIII	83	22	45	10	128	32	160	4.0 : 1
XIX	53	7	53	12	106	19	125	5.5 : 1
XX	78	14	61	16	139	30	169	4.6 : 1
XXI	56	16	55	12	111	28	139	4 : 1
XXII	52	19	41	6	93	25	118	3.7 : 1
XXIII	19	5	21	6	40	11	51	4 : 1
XXIV	8	1	3	1	11	2	13	5 : 1
XXV	43	15	50	9	93	24	117	4 : 1
XXVI	19	4	14	4	33	8	41	4 : 1
	1,385	360	1,224	345	2,609	705	3,314	

The four back crosses between the F_1 red females and males were made, and are recorded in the four following tables. In each case equality in four classes is expected. There can be little doubt that the results accord with the expectations, although the Reds once more run ahead of the Pinks.

Red ♀ (out of R ♀ × P ♂) × Pink ♂.

Bottle.	♀		♂		Total.		Grand Total.	Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.		
A	82	68	60	51	142	119	261	1.3 : 1
B	98	62	83	80	181	142	323	1.2 : 1
C	86	63	71	71	157	134	291	1.2 : 1
Total	266	193	214	202	480	395	875	
						Average proportion		1.2 : 1

Red ♂ (out of R ♀ × P ♂) × Pink ♀.

Bottle.	♀		♂		Total.		Grand Total.	Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.		
A	123	110	102	98	225	208	433	1.+ : 1
B	156	141	142	114	298	255	553	1.2 : 1
C	57	23	49	40	97	63	160	1.5 : 1
Total	336	274	263	252	620	526	1,146	
							Average proportion	1.2 : 1

Red ♀ (out of P ♀ × R ♂) × P ♂.

Bottle.	♀		♂		Total.		Grand Total.	Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.		
A	205	169	168	175	373	344	717	1.1 : 1
B	127	73	124	64	251	137	388	1.8 : 1
C	47	45	54	48	101	93	194	1.1 : 1
D	142	63	139	77	281	140	421	2 : 1
E	77	99	85	102	162	201	383	0.8 : 1
F	97	87	84	68	181	155	336	1.1 : 1
	695	536	654	534	1,349	1,070	2,439	
							Average proportion	1.26 : 1

Red ♂ (out of P ♀ × R ♂) × Pink ♀.

Bottle.	♀		♂		Total.		Grand Total.	Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.		
A	125	77	120	78	245	155	400	1.5 : 1
B	171	115	156	81	327	196	523	1.7 : 1
C	65	28	50	21	115	49	164	2.3 : 1
	361	220	326	180	687	400	1,087	
							Average proportion	1.7 : 1

The two counter-crosses were also made and are given in the two following tables. In both cases the expectation is 3 Reds to 1 Pink. In one case the ratio is 4 to 1 and in the other 3.4 to 1. Again, the Pinks run behind, but the ratios are not far from expectation.

R ♀ (out of P ♀ × R ♂) × R ♂ (out of R ♀ × P ♂).

Bottle.	♀		♂		Total.		Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.	
A	167	30	169	46	336	76	4.4 : 1
B	166	49	166	42	332	91	3.6 : 1
C	240	44	192	61	432	105	4.1 : 1
	573	123	527	149	1,100	272	
						Average proportion	4 : 1

Red ♀ (*out of R* ♀ × *P* ♂) × *Red* ♂ (*out of P* ♀ × *R* ♂).

Bottle.	♀		♂		Total.		Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.	
A	206	74	237	63	443	137	3.2 : 1
B	31	6	19	8	50	14	3.6 : 1
C	401	113	319	88	720	201	3.5 : 1
	638	193	575	159	1,213	352	
					Average proportion		3.4 : 1

In order to see if the amount of moisture in the bottles had any influence on the results, counts were made from day to day from two bottles that were quite wet at the beginning, when the first flies emerged, and were kept wet until the last flies had been counted. In the next two tables the results are given. They seem to indicate that as the bottle gets older the Pinks increase proportionately in number, and, towards the end, may actually exceed the Reds.

Red ♀ (*out of P* ♀ × *R* ♂) × *Pink* ♂. *Wet bottle.*

	♀		♂		Total.		Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.	
Count 1	1	—	12	1	13	1	2.27 : 1
Count 2	4	2	7	5	11	7	
Count 3	—	3	1	—	1	3	
Count 4	4	7	8	3	12	10	1.2 : 1
Count 5	32	35	36	25	68	60	1.13 : 1
Count 6	63	45	47	41	110	86	1.27 : 1
	27	27	13	22	40	49	0.81 : 1
	5	11	8	4	13	15	0.96 : 1

Red ♂ (*out of P* ♀ × *R* ♂) × *Pink* ♀. *Wet bottle.*

♀		♂		Total.		Proportion of Red to Pink.
Red.	Pink.	Red.	Pink.	Red.	Pink.	
1	2	1	—	2	2	0.9 : 1
1	2	1	1	2	3	
3	2	—	1	3	3	
25	23	13	12	38	35	1.1 : 1
18	27	19	22	37	49	0.75 : 1
7	6	8	8	15	14	1.07 : 1

The consecutive counts of two "dry" bottles, that were fairly dry when the flies began to emerge, are given in the next two tables.

R ♀ (*out of R* ♀ × *P* ♂) × *P* ♂. *Dry bottle.*

	♀		♂		Total.		Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.	
Count 1	7	1	2	1	9	2	4.5 : 1
Count 2	27	11	23	7	50	16	3.12 : 1
Count 3	33	35	25	25	58	60	0.96 : 1
Count 4	17	27	11	8	28	35	0.80 : 1
Count 5	12	7	10	4	22	11	2.0 : 1
Count 6	10	7	8	12	18	19	0.95 : 1

R ♂ (*out of Pink* ♀ × *Red* ♂) × *P* ♀. *Dry bottle.*

	♀		♂		Total.		Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.	
Count 1	14	8	8	11	22	19	1.16 : 1
Count 2	17	13	17	14	34	27	1.25 : 1
Count 3	10	12	12	10	22	22	1.00 : 1
Count 4	19	10	14	15	33	25	1.32 : 1
Count 5	20	17	39	28	59	45	1.31 : 1
Count 6	9	12	7	9	21	16	0.76 : 1
Count 7	5	3	7	13	12	16	0.75 : 1

At the time the count began, the bottles were covered with cloth, in order that the contents might dry out faster. The first counts, therefore, represent average conditions, but towards the end the bottles had become very dry. The entire count in these, and in the two preceding tables, covered about ten days. These last two tables seem also to show a constant change in the direction of relatively more Pinks.

Other conditions than moisture or dryness must be responsible for these results. In order to get data for comparison the early records of two other bottles, selected at random, are given in the next tables. These bottles also became drier towards the end as no fresh food was added. The first table seems to show a change, as before, but not so great. In the second, the change is also seen (if we reject the last two counts) but is not so marked. It is quite possible, therefore, that while dryness may make the conditions less favorable for the Pinks, it is evident that the change in ratio may be explicable on the assumption that the Pinks develop more slowly than the Reds.

R ♂ (*out of P* ♀ × *R* ♂) × *P* ♀.

	♀		♂		Total.		Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.	
Count 1	6	3	7	4	13	7	2.6 : 1
Count 2	21	4	21	10	42	14	
Count 3	75	38	66	28	141	66	2.13 : 1
Count 4	8	7	12	7	20	14	1.43 : 1
Count 5	29	27	20	16	49	43	1.14 : 1
Count 6	32	16	30	26	62	42	1.47 : 1

Red ♀ (*out of P* ♀ × *R* ♂) × *Pink* ♂.

	♀		♂		Total.		Proportion of Red to Pink.
	Red.	Pink.	Red.	Pink.	Red.	Pink.	
Count 1	8	7	9	1	17	8	2.15 : 1
Count 2	6	4	5	1	11	5	
Count 3	12	4	12	8	24	12	2 : 1
Count 4	48	28	47	31	95	59	1.6 : 1
Count 5	23	19	26	13	49	32	1.53 : 1
Count 6	12	4	12	3	24	7	2.6 : 1
Count 7	18	7	13	7	31	14	

The different ratios of Reds to Pinks seen in these and my former experiment

are puzzling. I am inclined to attribute them to differences in the running out of the bottles, so that delay in hatching affects the results. As a consequence my former experiments fall short of giving the complete number of the Pinks.

It may seem possible that the small number of Pinks in the earlier experiments may have been due to the red females having been fertilized by red males before they were isolated. It was, in fact, with this possibility in view, at that time, that I asked Miss Julia Moody to repeat the experiment. The stock bottles were carefully emptied every twelve hours, and only those females used for pairing in which the wings had not yet expanded, and in which the abdomen was still elongated. The results that Miss Moody obtained were substantially the same that I had also obtained, and both results were added together to make the sum total. It seems reasonable, therefore, to conclude that the Pinks used at first were relatively less viable than those used a year later in the present experiments.

RECORDS OF F_2 REDS AND PINKS (MOODY).

Bottle.	♀		♂		Total.		Proportion of Red to Pink.	Total.
	Red.	Pink.	Red.	Pink.	Red.	Pink.		
I	18	3	23	1	41	4	10.2 : 1	45
II	27	1	26	1	53	2	26 : 1	55
III	19	–	11	1	30	1	30 : 1	31
VI	41	7	27	6	68	13	5.2 : 1	81
VII	19	–	8	1	27	1	27 : 1	28
VIII	30	7	20	6	50	13	3.8 : 1	63
IX	20	16	37	9	57	25	2.3 : 1	82
X	18	2	18	9	36	11	3.3 : 1	47
XI	39	–	21	7	60	7	8.6 : 1	67
XII	29	9	22	4	51	13	4 : 1	64
XIII	11	2	10	2	21	4	5 : 1	25
XIV	18	2	22	–	40	2	20 : 2	42
XV	23	1	8	4	31	5	6.2 : 1	36
XVI	15	2	3	1	18	3	6 : 1	21
XVII	18	5	18	7	36	12	3 : 1	48
XVIII	7	2	13	–	18	2	9 : 1	20
XIX	9	12	3	3	12	15	0.8 : 1	27
XX	16	3	13	7	29	10	3 : 1	39
XXI	7	4	4	2	11	6	2 : 1	17
XXII	13	2	8	–	21	2	10 : 1	23
XXIII	22	4	11	4	33	8	4 : 1	41
XXIV	8	2	8	2	16	4	4 : 1	20
XXV	6	1	8	2	14	3	5 : 1	17
XXVI	10	1	3	2	13	3	4 : 1	16
XXVII	13	5	17	2	30	7	4.3 : 1	37
XXVIII	14	6	14	5	28	11	2.5 : 1	39
XXIX	12	3	13	1	25	4	6 : 1	29
XXX	29	1	17	1	46	2	23 : 1	48
XXXI	14	4	11	2	25	6	4 : 1	31
XXXII	13	2	19	3	32	5	6.4 : 1	37
XXXIII	6	2	3	–	9	2	4.5 : 1	11
XXXIV	11	–	3	1	14	1	14 : 1	15
XXXV	7	–	12	1	19	1	19 : 1	20
XXXVI	14	1	15	2	29	3	10 : 1	32
XXXVII	6	2	7	3	13	5	2.6 : 1	18
XXXVIII	1	2	7	1	8	3	3 : 1	11
XXXIX	15	3	17	2	32	5	6.4 : 1	37
XL	22	3	8	3	30	6	5 : 1	36
XLI	15	3	6	4	21	7	3 : 1	28
XLII	21	1	17	2	38	3	13 : 1	41
XLIII	7	4	5	2	12	6	2 : 1	18

RECORDS OF F_2 REDS AND PINKS (MOODY)—(*Continued*).

Bottle.	♀		♂		Total.		Proportion of Red to Pink.	Total.
	Red.	Pink.	Red.	Pink.	Red.	Pink.		
XLIV	18	4	12	–	30	4	7.3 : 1	34
XLV	12	11	13	2	25	13	2 : 1	38
XLVI	24	7	19	6	43	13	3.2 : 1	56
XLVII	12	–	11	2	23	2	12 : 1	25
XLVIII	16	4	6	3	22	7	3 : 1	29
XLIX	35	16	19	7	54	23	2.2 : 1	77
L	17	3	14	4	31	7	4.4 : 1	38
LI	10	2	5	1	15	3	5 : 1	18
LII	20	5	21	1	41	6	7 : 1	47
LIII	9	6	4	4	13	10	1.3 : 1	23
LIV	14	2	19	4	33	6	5.5 : 1	39
LV	13	5	7	2	20	7	3 : 1	27
LVI	23	3	12	–	35	3	12 : 1	38
LVII	28	8	17	2	45	10	4.5 : 1	55
LVIII	11	2	7	2	18	4	4.5 : 1	22
LIX	6	9	6	6	12	15	0.8 : 1	25
LX	17	1	20	1	37	2	18 : 1	39
LXI	26	4	7	4	33	8	4 : 1	41
LXII	6	6	8	5	14	11	1 : 1	25
LXIII	10	1	8	–	18	1	18 : 1	19
LXVI	11	3	11	4	22	7	3 : 1	29
LXVII	7	3	8	3	15	6	2.5 : 1	21
LXVIII	21	6	10	8	31	14	2.2 : 1	45
LXIX	13	1	10	9	23	10	2.2 : 1	33
LXX	15	8	18	3	33	11	3.0 : 1	44
LXXI	17	3	16	6	33	9	3.6 : 1	42
LXXII	7	–	6	4	13	4	3.0 : 1	17
LXXIII	10	5	12	4	22	9	2.5 : 1	31
LXXIV	8	3	7	1	15	4	4 : 1	19
LXXV	12	6	13	2	25	8	3 : 1	33
LXXVI	20	4	10	1	30	5	6 : 1	35
LXXVII	35	8	35	4	70	12	5.6 : 1	82
LXXVIII	28	10	21	3	49	13	3.8 : 1	62
LXXIX	14	1	12	–	26	1	26 : 1	27
LXXX	21	5	8	5	29	10	3 : 1	39
LXXXI	23	9	20	3	43	12	3.6 : 1	55
LXXXII	27	7	7	8	34	15	2.3 : 1	49
LXXXIII	7	–	9	1	16	1	16 : 1	17
LXXXIV	25	2	7	1	32	3	11 : 1	35
LXXXV	21	12	23	5	44	17	2.6 : 1	51
LXXXVI	16	3	14	9	30	12	2.5 : 1	42
LXXXVII	19	8	22	3	41	11	3.7 : 1	52
LXXXVIII	21	2	13	5	34	6	6.7 : 1	40
LXXXIX	13	–	15	1	28	1	28 : 1	29
XC	21	3	8	3	29	6	5 : 1	35
XCI	13	3	10	–	23	3	8 : 1	26
XCII	1	2	3	1	4	3	1.3 : 1	7
XCIII	5	2	7	–	12	2	6 : 1	14
XCIV	21	10	8	5	29	15	2 : 1	44
XCV	13	1	6	3	19	4	5 : 1	23
XCVI	25	–	23	1	48	1	48 : 1	49
XCVII	10	3	4	4	14	7	2 : 1	21
XCVIII	2	1	6	1	8	2	4 : 1	10
XCIX	2	1	5	1	7	2	3.5 : 1	9
C	2	–	2	1	4	1	4 : 1	5
CI	1	3	4	–	5	3	1.7 : 1	8
CII	3	2	4	2	7	4	3.5 : 1	11
CIII	2	–	2	2	4	2	2 : 1	6
	1,521	368	1,190	289	2,711	657		3,368
					Average proportion		4.127 : 1	

In order that the full data may be recorded for this interesting case, Miss Moody's records may now be given in detail, where the record of each bottle containing a single pair each is recorded. For convenience these bottles in which the F_2 flies contained all four (or three of the four) expected classes are first given (99 bottles in all), and then the records of 32 bottles in which only red flies appeared in the second generation are given. If the latter 32 bottles be excluded the ratio of Reds to Pinks is found to be 4.127 to 1, which is not very different from the results obtained by Mr. Litt. But as I have stated there is no sufficient reason for excluding these 32 cultures. The small number of offspring obtained from certain pairs is significant, and can scarcely be due to sterility. As small bottles or vials were used in these experiments it is not improbable that all of the offspring were not obtained; and, as already pointed out, failure to run each bottle to completion (*i. e.* more than the prescribed ten days after the first flies hatched) would cut down the Pinks disproportionately to the Reds.

RECORDS OF F_2 REDS (MOODY).

Bottle.	♀	♂	Total.	Bottle.	♀	♂	Total.
I	31	27	58	XXII	28	26	54
II	38	33	71	XXIII	9	8	17
III	40	21	61	XXIV	20	16	36
IV	41	31	72	XXV	32	9	41
V	22	15	37	XXVI	18	15	33
VI	7	6	13	XXVII	32	32	64
VII	11	9	20	XXVIII	11	21	32
VIII	25	19	44	XXIX	9	8	17
IX	18	12	30	XXX	15	4	19
X	25	33	58	XXXI	2	2	4
XI	3	7	10	XXXII	19	17	36
XII	22	27	49	XXXIII	7	16	23
XIII	35	25	60	XXXIV	20	18	38
XIV	3	7	10	XXXV	19	16	35
XV	20	14	34	XXXVI	9	7	16
XVI	31	12	43	XXXVII	2	6	8
XVII	12	8	20	XXXVIII	3	3	6
XVIII	18	16	34	XXXIX	5	4	9
XIX	13	13	26	XL	2	2	4
XX	14	12	26	XLI	5	5	10
XXI	13	12	25	XLII	1	3	4
					710	597	1,307

THE PINK-ORANGE RATIO.

In my former paper a peculiar result was recorded in the F_2 generation when pink males were mated to orange females. I stated that I "could offer no reasonable explanation of this peculiar relation." In this cross I found for instance, that while in the F_1 generation (that gave pink females and orange males) the two sexes were approximately equal in numbers, in the F_2 generation, on the other hand, the following proportions were obtained: Pink ♀ 572, Pink ♂ 292, Orange ♀ 312, Orange ♂ 522. There were twice as many pink females as pink males; but only half as many orange females as orange males. The result could not be attributable here to differences in the viability of the pink and orange

males, because in the reciprocal cross equal numbers of pink males and orange males were present. In order to study this exceptional case I have repeated the experiment and at the same time have mated pairs of F_1's, and made back-crosses and counter-crosses. The repetition has shown that the peculiar ratio was the result of some error in the experiment, since the new results conform to expectation. The other crosses have also shown that there is nothing unusual in this case. Incidentally the new data give a searching test of the correctness of the general explanation of eye-color, and give a welcome addition to the facts previously recorded.

When orange females were crossed to pink males all the female offspring were Pink and all the male offspring Orange. The new numerical results for the first and second generations were as follows:

$$\text{Orange } ♀ \text{ by Pink } ♂ = \begin{cases} \text{Pink } ♀ \ 969 \begin{cases} \text{Pink} & ♀ \ 1{,}738 \\ \text{Pink} & ♂ \ 1{,}641 \end{cases} \\ \text{Orange } ♂ \ 941 \begin{cases} \text{Orange} & ♀ \ 1{,}846 \\ \text{Orange} & ♂ \ 1{,}621 \end{cases} \end{cases}$$

The results of each bottle given separately show how evenly the results run.

$$\begin{matrix} O \ ♀ \text{ by } P \ ♂ & P_1 \\ P \ ♀ \quad O \ ♂ & F_1 \end{matrix}$$

	$P♀$	$P♂$	$O♀$	$O♂$		$P♀$	$P♂$	$O♀$	$O♂$
1	91	80	87	75	10	50	50	40	29
2	85	79	75	66	11	44	44	35	38
3	76	43	33	37	12	106	106	82	119
4	73	67	63	55	13	156	157	181	170
5	102	70	90	73	14	42	36	35	40
6	44	41	45	44	15	192	224	176	226
7	30	30	25	24	16	65	76	81	90
8	23	20	25	23					
9	10	5	4	2	Total	1,187	1,128	1,077	1,105

The result gives a close approximation to expectation. There is nothing unusual in the ratios. Some error must have arisen in the course of the former experiment that is most regrettable. There can be no doubt that the counts were accurately made, for, at the time we commented on the peculiar ratio that was appearing. The error must have arisen in the mating. If by chance one or more parent flies (♀'s) (*i. e.*, orange ♀ by pink ♂) had been accidentally left over in the culture bottle the error can be explained; for, as seen above, the presence of such flies would increase the ratio of pink ♀'s and of orange ♂'s which added to the F_2 count would give the recorded results. I am inclined to account for the error as due to this oversight, because without the utmost care F_1 flies may be left in the old bottle when the parents are supposed to be removed. We are on our guard against this danger, and usually take the precaution of removing all the old food and looking over it carefully to see that no flies have been left sticking

to it. But if one or two females were left behind they would go over with the F_1 flies and contaminate the second generation. As a rule the parent flies are left for ten days in the first culture bottle, and then taken out and destroyed or placed in a new bottle. On the eleventh or twelfth day the F_2 flies begin to appear, and are removed daily for the next ten days, when the bottle is thrown out, for fear that F_3 flies might appear. In this way the overlapping of generations is avoided.

In addition to the preceding mass cultures the next table gives the counts of twenty pairs. The results run as evenly as those of the mass cultures and show that the former represent the actual outcome of the cross; *i. e.*, they show the same range of variability.

O ♀ by *P* ♂
P ♀ *O* ♂

	P♀	*P*♂	*O*♀	*O*♂		*P*♀	*P*♂	*O*♀	*O*♂
1	50	38	46	34	12	34	33	25	34
2	22	22	14	23	13	34	22	17	21
3	7	6	1	5	14	26	26	24	20
4	21	27	35	25	15	34	39	31	34
5	53	37	38	55	16	25	20	19	24
6	30	24	21	24	17	31	25	23	31
7	29	24	28	30	18	10	12	16	18
8	13	16	13	17	19	9	5	3	4
9	27	34	29	32	20	15	15	10	17
10	53	52	46	42	Total	550	513	469	516
11	34	36	30	24					

The reciprocal experiment, in which the pink female is paired to the orange male, was also repeated with the following results:

$$\text{Pink ♀ by Orange ♂} = \left\{\begin{matrix}\text{Pink ♀ } 1{,}264\\ \text{Pink ♂ } 976\end{matrix}\right\} = \left\{\begin{matrix}\text{Pink ♀ } 437\\ \text{Pink ♂ } 217\\ \text{Orange ♂ } 184\end{matrix}\right.$$

These results agree with those of the earlier experiment. When the F_2 flies of both experiments are added together they give the following result:

Pink ♀ 1,472
Pink ♂ 729 F_2
Orange ♂ 702

Pink-Orange Back-Crosses and Other Tests.

The correctness of the formulæ can be tested in several ways by back-crossing, counter-crossing and out-crossing. The following results show convincingly the correctness of the symbolism used. I do not doubt that the results might be formulated in a different way, but the principle involved would remain the same, and it is the principle involved rather than the particular way of expressing the relation that is the important point at issue.

The F_1 Back-Crosses.—The two following schemes give the F_1 generation:

P_1	O ♀ by P ♂	P_1	P ♀ by O ♂
F_1	P ♀ O ♂	F_1	P ♀ P ♂

When P ♀ (from O ♀ by P ♂) is back-crossed to P ♂ the expectation is 2 pink ♀, 1 pink ♂, 1 orange ♂. The results gave:

F_1	Pink ♀ 31	Pink ♂ 18	Orange ♂ 15

When P ♀ (from P ♀ by O ♂) is back-crossed to O ♂ the expectation is for equality in all four classes. The results gave:

F_1	Pink ♀ 106	Pink ♂ 76	Orange ♀ 120	Orange ♂ 100

Further Tests of F_1.—In several cases the F_1's were tested with the other color from pure stock. Thus: When P ♀ (from O ♀ by P ♂) is mated with pure O ♂ the expectation is for equality in all four classes. The actual results were:

Pink ♀	110	Pink ♂	109	Orange ♀	91	Orange ♂	100
	102		70		90		73
	44		41		45		44
	256		220		226		217

When P ♂ (from P ♀ by O ♂) is tested with pure O ♀ the expectation is pink ♀ and orange ♂ in equal numbers: The results were:

Pink ♀	283	Orange ♂	278
	109		107
	393		385

When P ♀ (from P ♀ by O ♂) is tested with P ♂ the expectation is 2 pink ♀, 1 pink ♂, 1 orange ♂: The results were:

Pink ♀ 46	Pink ♂ 20	Orange ♂ 19

Counter-Crosses.—The F_1's from O ♀ by P ♂ were mated to the F_1's from P ♀ by O ♂. Such crosses I shall call counter-crosses.

When P ♀ (from P ♀ by O ♂) is mated to the O ♂ (from O ♀ by P ♂) the expectation is for equality in four classes. The results were:

Pink ♀	66	Pink ♂	59	Orange ♀	80	Orange ♂	53
	44		103		115		113
	110		162		195		166

When P ♀ (from O ♀ by P ♂) is mated to O ♂ (from P ♀ by O ♂) the expectation is 2 pink ♀, 1 pink ♂, 1 orange ♂. The results were:

Pink ♀ 157	Pink ♂ 22	Orange ♂ 73

Other Tests of the F_1 Pink-Orange Cross.

The following data are of interest in that they confirm the general scheme of explanation. The F_1 pink females were tested with red and with vermilion flies of pure strains. The experiments were made by Mr. A. H. Sturtevant to whom I am indebted for the data:

When *P* ♀ (from *O* ♀ by *P* ♂) was crossed to *R* ♂, the following classes were produced:

Red ♀ 98 Red ♂ 66 Vermilion ♂ 34

The analysis of the combination follows:

vpOX——vpOX	Orange	♀	P_1
vPOX——vpo	Pink	♂	P_1
vpOXvPOX	Pink	♀	(F_1)
VPOXVpo	Red	♂	(pure strain)
vpOXVPOX	Red	♀	F_2
vPOXVPOX	Red	♀	F_2
vpOXVpo	Vermilion	♂	F_2
vPOXVpo	Red	♂	F_2

The expectation is that the red females equal the sum of the other two classes and this is closely realized; the vermilion males run behind however and this deficiency may seem (?) to be made good by the excess of the red males.

When *P* ♀ (from *O* ♀ by *P* ♂) is mated to vermilion ♂ of a pure strain the offspring were:

Red ♀ 74 Red ♂ 54 Vermilion ♀ 57 Vermilion ♂ 34

The males run behind the females, and the vermilion behind the reds.

The analysis is as follows:

vpOX——vpOX	Orange	♀	P_1
vPOX——vpo	Pink	♂	P_1
vpOXvPOX	Pink	♀	(F_1)
VpOXVpo	Vermilion	♂	(pure)
vpOXVpOX	Vermilion	♀	F_2
vPOXVpOX	Red	♀	F_2
vpOXVpo	Vermilion	♂	F_2
vPOXVpo	Red	♂	F_2

When *P* ♀'s (from *P* ♀ by *O* ♂) are mated to red males of pure strain the results were:

Red ♀ 38 Red ♂ 12 Vermilion ♂ 17

The analysis is as follows:

vPOX—vPOX	Pink	♀	P_1
vpOX—vpo	Orange	♂	P_1
vPOX—vpOX	Pink	♀	(F_1)
VPOX—Vpo	Red	♂	(pure strain)
vPOXVPOX	Red	♀	F_2
vpOXVPOX	Red	♀	F_2
vPOXVpo	Red	♂	F_2
vpOXVpo	Vermilion	♂	F_2

The numbers are small, but they agree fairly with the expectation. It will be noticed that the vermilion males are actually ahead of the red males.

When *P* ♀'s (from *P* ♀ by *O* ♂) are mated to vermilion males of pure strain the results were:

Red ♀ 57 Red ♂ 45 Vermilion ♀ 57 Vermilion ♂ 41

The analysis follows:

vPOX—vPOX	Pink	♀	P_1
vpOX—vpo	Orange	♂	P_1
vPOX—vpOX	Pink	♀	(F_1)
VpOX—Vpo	Vermilion	♂	(pure strain)
vPOXVpOX	Red	♀	F_2
vpOXVpOX	Vermilion	♂	F_2
vPOXVpo	Red	♀	F_2
vpOXVpo	Vermilion	♂	F_2

In this experiment the vermilion hold their own well.

The Vermilion-Pink Ratio.

In the cross between vermilion female and pink male recorded in my former paper there appeared in the F_2 generation twice as many pink ♀ as pink ♂ and twice as many orange ♀ as orange ♂. The numbers however were small, and it was not clear whether they had any significance. I have repeated the experiment on a larger scale, and have found that the numbers were not significant. A number of back-crosses were also carried out and counter-crosses which may be given since they also furnish a further and desirable confirmation of the general explanation of the heredity of eye color. The F_2 records are given separately in the next table:

There is nothing unusual in the results and even the separate records run fairly evenly. As usual the pink and orange classes fall below the expectation (3 to 1).

		R♀	*R*♂	*V*♀	*V*♂	*P*♀	*P*♂	*O*♀	*O*♂
Vermilion ♀ by Pink ♂ =	721 Red ♀	63	57	45	67	10	12	10	17
		102	73	81	60	30	29	23	19
		55	61	65	70	13	17	23	15
		56	47	58	55	12	12	17	8
		166	158	166	135	34	23	30	29
		127	96	109	76	23	24	27	20
	Verm. ♂ 706	94	72	58	75	17	12	15	6
		173	196	173	161	48	29	35	42
		88	76	91	87	19	16	19	15
		96	76	105	79	22	18	21	16
		82	114	93	82	20	9	24	19
		53	75	56	43	10	16	16	16
Total		1,145	1,101	1,100	990	222	217	260	222

The reciprocal cross, Pink ♀ by Vermilion ♂, was also repeated as a safeguard, although nothing unusual had appeared before, and again the results are regular as shown in the next table:

		R♀	*R*♂	*V*♂	*P*♀	*P*♂	*O*♂
Pink ♀ by Vermilion ♂	Red ♀	154	78	64	16	0	8
		147	37	76	9	3	11
		213	78	67	35	4	15
	Red ♂	154	96	80	32	13	14
		126	65	68	31	17	11
		215	111	87	45	24	21
		25	8	14	9	8	6
Total		1,034	473	456	167	69	86

The following back-crosses were carried out. As the results were regular in all cases no comment or analysis is called for:

	R♀	*R*♂	*V*♂	*P*♀	*P*♂	*O*♂
R♀ (from *V*♀ by *P*♂) by *P*♂ =	129	60	49	117	60	42

	R♀	*R*♂	*V*♀	*V*♂
R♀ (from *P*♀ by *V*♂) by *V*♂ =	99	106	113	83

	R♀	*R*♂	*P*♀	*P*♂	*V*♂	*O*♂
R♀ (from *P*♀ by *V*♂) by *P*♂ =	25	8	9	8	14	6

	R♀	*V*♂
R♂ (from *P*♀ by *V*♂) by *V*♀ =	424	453

	R♀	*R*♂	*V*♀	*V*♂	*P*♀	*P*♂	*O*♂
V♂ (from *V*♀ by *P*♂) by *P*♀ =	286	232	10	2	209	184	6

The expectation in the last cross calls only for Reds and Pinks. The small additional classes must be due to a mutation in *P* ♀ due to loss of *P* in some eggs (or possibly to the presence of an orange ♀ in the pinks). These small classes did not appear in one bottle that gave only Reds and Pinks.

The Vermilion-White Cross.

This cross has been made by Mr. A. H. Sturtevant in my laboratory, to whom I am indebted for the following data. When a white male (of red-white stock) was bred to vermilion female of pure stock the results were:

White ♂ by vermilion ♀ = Red ♀ 25, Vermilion ♂ 24 { Red ♀ 242, Red ♂ 63, Vermilion ♀ 228, Vermilion ♂ 165, White ♂ 163

The analysis is as follows:

F_1

VpOCX—VpOCX Vermilion ♀
VPocX—Vpoc White ♂

VpOCX—VPocX Red ♀
VpOCX—Vpoc Vermilion ♂

VpocX—VpOCX—VPocX—VPOCX
VpOCX —Vpoc

VpocX	*VpOCX*	= Vermilion ♀	*VpocX*	*Vpoc*	= White ♂
VpOCX	*VpOCX*	= Vermilion ♀	*VpOCX*	*Vpoc*	= Vermilion ♂
VPocX	*VpOCX*	= Red ♀	*VPocX*	*Vpoc*	= White ♂
VPOCX	*VpOCX*	= Red ♀	*VPOCX*	*Vpoc*	= Red ♂

The only point in the result that calls for comment is the small number of red ♂'s in the F_2 generation. Without any coupling that class should be equal to the vermilion male class, but the result is explicable when the coupling between *P* and *C* is recognized. The white males without coupling should be equal to the sum of the vermilion and red males but the white males are not quite so numerous as the vermilion males alone. This result can be explained as due to the lower viability of the whites, a circumstance known to exist, from other experiments.

In the analysis two classes of vermilion females should occur, one homozygous for *C* and one heterozygous; the latter being less frequent, owing to coupling. Nine of these ♀'s taken at random were tested and seven proved to contain *CC* and two *Cc*. Nine of the white males were also tested, and seven were found to contain *Pp*, and two to contain *pp*. This result is in harmony with the assumption of coupling between *P* and *C*.

The Eosin Eye.

During the summer of 1911 I carried on a mass culture of white-eyed flies, with black body-color, and miniature wings, in order to get a pure white-eyed stock combined with black miniature wings. This stock had been derived recently from a stock of black, miniature flies derived from pink- or red-eyed ancestors. As mass cultures were used, the possibility of a cross with Red or Pink

occurring before the new flies were isolated, existed, since the flies were isolated only each twenty-four hours. If so, even although white alone was present the eggs might have been fertilized by a red fly which died before the flies were examined. Although the stock remained pure I found nevertheless an individual whose eyes were different in color from any color with which I was then familiar. The fly was isolated and bred to white-eyed flies of the same stock. In the next generation some flies with the new color appeared, and from these two stocks were subsequently produced; a stock pure for the color, and the other having some flies with the eyes of this color and others with white eyes. For some time I spoke of the new eye color as a mutation upwards; from white to color, something that I have never seen before. That such a change really occurred may seem improbable, when the relation of the white to the colored eye is considered, as will be shown below. It may seem more likely that at the time the colored flies had not been entirely removed from the culture and that the mutation had occurred before or at the time of separation. Therefore, until mutation upwards appears again such an origin will seem to the advocates of the presence and absence theory well nigh inconceivable.

Since the preceding account was written the eosin eye has appeared twice as a mutant in red stock. In both cases the single fly that appeared has been tested with Orange and shown to give the same results as does the eosin stock. In one of these cases the fly arose in a mass culture; in the other case an individual (a male) appeared amongst the offspring of an isolated pair of wild red flies from stock that had been inbred for two years. There can remain no doubt that the mutant arose through the loss of the orange factor in the red-eyed fly as its formulæ *VPoC* would most naturally lead one to infer.

During the course of the experiments with eye colors we had often commented on the fact that the orange factor had never been lost. Its location in the complex could not therefore be determined. When the new eye appeared the suspicion that it might be due to the loss of the orange factor at once arose, and was put to the test. If orange alone was lost the new mutant when crossed to orange should give one of the higher colors in the series.

One peculiarity of this eye, first noted by Mr. C. B. Bridges, my assistant, to whom the new eye was entrusted for experimentation, is that two distinct colors may be easily distinguished.

In pure cultures the females, Plate XXVIII, fig. 7, have darker eyes than the males, fig. 9. The "dark" eosin eye of the dark female is more nearly like the pink eye than like any other; while the light eosin eye of the male is more like the orange eye, but is yellowish, and more translucent.

If, however, the dark eosin females be crossed with white males, fig. 10, of their own stock the daughters will have light eyes, fig. 8, like those of the eosin males, fig. 9. This must mean that the dark eosin eye is due to some factor or factors in duplex, and the light eosin eye to the same factor in simplex. The tests made by Mr. Bridges showed, in fact, that this is the explanation, and that the factor

involved is the *C* factor, which in the female can appear in duplex where it gives dark eosin, while in simplex, as in the heterozygous females, and in all males, it gives the light eosin color. On the other hand, the factors *V* and *P* while essential for the production of the eosin color may be present either in simplex or in duplex without any *distinguishable* difference in shade.

When (dark) eosin females are mated to orange males there result red-eyed females and (light) eosin males. The red females could only be produced if the new mutant contained both the *V* and *P* factors, since previous experiments had shown that the orange male lacks these factors. Since the males were not red, the male-producing sperm of the orange-eyed fly lacks orange. In other words, the factor for orange is sex-linked. The analysis of the last cross is, therefore, as follows:

VPoCX—VPoCX		Dark-eosin ♀
vpOCX —vpoc		Orange ♂
VPoCX	*vpOCX*	Red ♀
VPoCX	*vpoc*	Light-eosin ♂

Crosses Within the Eosin Stock.

Dark-eosin ♀ by Eosin ♂.

When the eosin females of the darker eye color are mated to eosin males the female offspring have Dark-eosin eyes and the males Light-eosin eyes:

Dark-eosin ♀ by eosin ♂ { Dark-eosin ♀ 765 / Light-eosin ♂ 836

The analysis is as follows:

VPoCX—VPoCX	Dark-eosin ♀
VPoCX—Vpoc	Light-eosin ♂
VPoCXVPoCX	Dark-eosin ♀
VPoCXVpoc	Light-eosin ♂

Light-eosin ♀ by Eosin ♂.

The parallel cross, in which both males and females have Light-eosin eyes, gave four classes of offspring as shown below:

Light-eosin ♀ by eosin ♂ = { Dark-eosin ♀ 420 / Light-eosin ♀ 357 / Light-eosin ♂ 370 / White-eosin ♂ 344

The analysis gives:

VPoCX—VPocX	Light-eosin ♀
VPoCX—Vpoc	Light-eosin ♂
VPoCXVPoCX	Dark-eosin ♀
VPoCXVPocX	Light-eosin ♀
VPoCXVpoc	Light-eosin ♂
VPocXVpoc	White-eosin ♂

Dark-eosin ♀ by White-eosin ♂.

When the Dark-eosin females are mated to White-eosin males, all of the offspring are Light-eosin. Thus:

Dark-eosin ♀ by White-eosin ♂ { Light-eosin ♀ 489 / Light-eosin ♂ 430

The analysis is:

VPoCX—VPoCX	Dark-eosin ♀
VPocX—Vpoc	White-eosin ♂
VPoCXVPocX	Light-eosin ♀
VPoCXVpoc	Light-eosin ♂

Light-eosin ♀ by White-eosin ♂.

When Light-eosin females are mated to White-eosin males, four classes of offspring result, as follows:

Light-eosin ♀ by White-eosin ♂ { Light-eosin ♀ 357 / White-eosin ♀ 370 / Light-eosin ♂ 357 / White-eosin ♂ 344

The analysis is:

VPoCX—VPocX	Light-eosin ♀
VPocX—Vpoc	White-eosin ♂
VPoCXVPocX	Light-eosin ♀
VPocXVPocX	White-eosin ♀
VPocXVpoc	Light-eosin ♂
VPocXVpoc	White-eosin ♂

White-eosin ♀ by Light-eosin ♂.

When White-eosin females are mated to Light-eosin males all the female offspring are Light-eosin and all the males White-eosin—a case of criss-cross inheritance:

White-eosin ♀ by Light-eosin ♂ = { Light-eosin ♀ 365 / White-eosin ♂ 332

The analysis is:

VPocX—VPocX	
VPocX—Vpoc	
VPocXVPoCX	Light-eosin ♀
VPocXVpoc	White-eosin ♂

White ♀ by White ♂.

The only remaining possible combination in this series is that of white female to white male of the eosin stock and vice-versa, which should give only white females and males. This is in fact realized:

White ♀ by White ♂ = { White ♀ 218 / White ♂ 189

It is seen that all the results are consistent with the assumption that the darker females are due to two doses of the *C* factor and the light females to one dose of the same factor. The two kinds of females differ in this one respect alone. The males having only one *X* have in consequence only one dose of the *C* factor, and are light in color, no dark males being possible.

In the red, vermilion, and pink-eyed flies no difference in shade between the females and males has been made out with certainty, although in these, as in the Eosin, the females have two doses of *P*, *O*, and *C*, and the males only one dose. Correspondingly, in the heterozygous flies of red and pink (made by crossing white males to females of these colors) no difference in shade was observed, although the heterozygous females had only one dose of *P*, *O* and *C*. But in the orange stock, mixed with "its own" white, Mr. Bridges has been able to distinguish two classes of females: very dark orange and light orange, which proved on being tested to contain respectively two doses and one dose of *O* and *C*. But in this case, unlike that of the Eosin, the orange males are like the *dark* (homozygous) females and not (as in the Eosin) like the *light*, orange females. In consequence a *light* orange male is as impossible as a *dark* eosin male. The following crosses will serve to illustrate the statements just made:

Dark orange ♂ by Light orange ♀	Dark orange ♀	190
	Dark orange ♂	182
	Light orange ♀	181
	White orange ♂	187
Light orange ♀ by White orange ♂	Light orange ♀	80
	Dark orange ♂	62
	White orange ♀	26
	White orange ♂	41
Light orange ♀ by Pink ♂	Pink ♀	117
	Dark orange ♂	61
	White orange ♂	70

Composition of the White Eye Mutants.

It has been shown that the assumption that the eosin eye lacks the orange factor, but contains *V* and *P*, is in conformity with the experimental tests. Its *white* associate lacks both the orange and the *C* factor as shown by the same tests. It has been possible to show that all white-eyed flies lack both *O* and *C*, and not simply *C* as formerly assumed.[1] This is made evident by crossing an eosin male to a white female (of the red class). All the female offspring should have red eyes if the ordinary white contained orange. But the female offspring from this cross do not have red eyes but light-eosin eyes. This latter condition can only

[1] Both assumptions however give the same results in all cases except where eosin is involved, and therefore the earlier view was justified.

arise if the ordinary (red) white female in question lacks both the orange and the *C* factor. Thus:

VPocX—VPocX	White (red) ♀
VPoCX—Vpoc	Eosin ♂
VPocXVPoCX	Light-eosin ♀
VPocXVpoc	White ♂

Crosses between the white male of orange stock with dark-eosin ♀ show that *O* and *C* are both absent from the orange-white stock also. Thus:

VPoCX—VPoCX	Dark-eosin	♀
vpocX—vpoc	White (orange)	♂
VPoCXopocX	Light-eosin	♀ 151
VPoCXopoc	Light-eosin	♂ 158

At that time we did not have in stock whites of the Pink and Vermilion stocks and could not make the same test with them, but there can be little doubt that the whites of these classes also lack *O* and *C*.

If true it follows that all white-eyed flies are alike in that they lack both orange and the color producer. They differ, as explained above, only in the presence or absence of the factors for *V* and *P*.

The Eye Color of "Permutants" Lacking *V*, *P* and *O*. Fig. 5.

Having flies that lack the orange factor, such for instance, as the dark-eosin fly *VPoCXVPoCX*, and flies that lack the vermilion and pink factors but contain *C*, such as the orange flies *vpOC*, it would seem possible by crossing and extracting to obtain some that would lack the factors for *V*, *P* and *O* but contain *C;* for instance, *vpoC*. One might expect these flies to be white-eyed; for, they would lack all the previously determined factors for eye-color, and possess only the color producer.

In order to make up flies of this sort we crossed dark-eosin females with orange males. Such a combination would give red females and eosin males. Those inbred should give the desired result as the following analysis will show:

VPoCX—VPoCX	Dark-eosin	♀
vpOCX—vpoc	Orange	♂
VPoCXvpOCX	Red	♀
VPoCXvpoc	Light-eosin	♂

vPoCX	*VpoCX*	*VPOCX*	*VPoCX*	*vpOCX*	*vpoCX*	*VpOCX*	*vPOCX*
		vPoCX	*VPoCX*	*vpoc*	*Vpoc*		

Females.		Males.	
vPoCXvPoCX	Pure pink	*vPoCXvpoc*	Pure pink
vPoCXVPoCX	Eosin	*vPoCXVpoc*	Eosin
VpoCXvPoCX	Eosin	*VpoCXvpoc*	Pure vermilion
VpoCXVPoCX	Eosin	*VpoCXVpoc*	Pure vermilion
VPOCXvPoCX	Red	*VPOCXvpoc*	Red
VPOCXVPoCX	Red	*VPOCXVpoc*	Red
VPoCXvPoCX	Eosin	*VPoCXvpoc*	Eosin
VPoCXVPoCX	Eosin	*VPoCXVpoc*	Eosin
vpOCXvPoCX	Pink	*vpOCXvpoc*	Orange
vpOCXVPoCX	Red	*vpOCXVpoc*	Vermilion
vpoCXvPoCX	Pure pink	*vpoCXvpoc*	Pure C
vpoCXVPoCX	Eosin	*vpoCXVpoc*	Pure vermilion
VpOCXvPoCX	Red	*VpOCXvpoc*	Vermilion
VpOCXVPoCX	Red	*VpOCXVpoc*	Vermilion
vPOCXvPoCX	Pink	*vPOCXvpoc*	Pink
vPOCXVPoCX	Red	*vPOCXVpoc*	Red

	Females.	Males.
Summary of F_2	6 Red	3 Red
	6 Eosin	3 Eosin
	2 Pink	3 Vermilion
	2 Pure pink	3 Pure vermilion
		1 Pink
		1 Pure pink
		1 Orange
		1 Pure C

The expectation shows that one class out of the thirty-two classes should contain males with the formula *vpoCXvpoc*. The other classes contain flies of known eye color, except pure pink females (*vPoCXvPoCX*) and pure pink males (*vPoCXvpoc*), and pure vermilion males (*VpoCXvpoc*). In fact a number of males (and a few females) were produced with a faint tinge to the eye, Plate XXVIII, fig. 5. So faint is this tinge in some of the classes that some of the flies would be passed over as whites, but a careful comparison with known whites shows that a faint color is actually present. It is best seen if the flies are kept several days after emerging.

It has been a difficult matter to refer all of these flies to their proper classes, and the full account of this new series of eye-colors, that contain *V* or *P* without *O*, will be left for another time. Here we are only concerned with the identification of the *vpoC* class.

The faintest class of males was picked out and mated to orange females. If these males were *C* males they should produce only orange flies in this cross. Thus:

vpOCX	*vpOCX*	Orange ♀
vpoCX	*vpoc*	CX ♂
vpOCX	*vpoCX*	Orange ♀[1]
vpOCX	*vpoc*	Orange ♂

[1] This is the first time we have produced an orange ♀ heterozygous for *O* but homozygous for *C*. As expected it is distinguishable from the form homozygous for both *C* and *O* (regular stock) by being lighter and yellower. It is slightly darker than the form which is heterozygous for both *C* and *O*. Thus while in the eosin *C* in simplex and in duplex are distinguishable, in this form *O* in simplex is distinguishable from *O* in duplex.

If the flies in question had been pure vermilion (*VpoCXVpoc*), they should give vermilions, or if pure pinks (*vPoCXvpoc*) they should give pink-eyed flies.

Since the cross gave only orange flies it follows that males had been produced that lacked all of the three determiners, but contained the color producer *C*. The remarkable fact is that these flies still show some color, which can mean either that the color producer itself produces a faint tinge of color, or that the color *C* is still complex, containing in addition to *C* some lesser determiners for eye color.

April 19, 1912.

DESCRIPTION OF PLATE XXVIII.

FIG. 1. Red-eyed fly (wild). *VPOC*.
FIG. 2. Vermilion-eyed fly. *VpOC*. Color should be more brilliant.
FIG. 3. Pink-eyed fly. *vPOC*.
FIG. 4. Orange-eyed fly. *vpOC*. Color is too red, should be more chrome yellow.
FIG. 5. Pure C-eyed fly lacking *V*, *P*, *O* = *vpoC*. Color should be fainter.
FIG. 6. White-eyed fly. *VPoc*.
FIG. 7. Eosin-eyed female, *VPoCX*, *VPoCX*. Miniature wings; black color. Color of eyes should be more pink.
FIG. 8. Light-eosin female *VPoCX*, *VPocX*. Miniature wings; black color.
FIG. 9. Eosin male, *VPoCX*, *Vpoc*. Miniature wings; black color.
FIG. 10. White-eosin male *VPocX*, *Vpoc*. Miniature wings; black color.

PLATE XXVIII.

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FIG. 9. Eosin male, *VPoCX, Vpoc.* Miniature wings; black color.
FIG. 10. White-eosin male *VPocX, Vpoc.* Miniature wings; black color.

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E. N. WALLACE, DEL

MORGAN: MUTATIONS IN EYE-COLOR OF DROSOPHILA.

On the Radiation of Energy

BY

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PHILADELPHIA
1912

ON THE RADIATION OF ENERGY.

By James E. Ives, Ph.D.

I propose in this paper to discuss the radiation of energy, including under this term the radiation from incandescent bodies, hot bodies, and electrical systems.

§ 1. Introduction.

By the expression radiant energy is usually meant that form of energy which is supposed to exist independently of matter. Thus we say that light and heat and electromagnetic disturbances pass from the sun to the earth, and, as far as we know, are not transported by any vehicle. The ether, which was formerly supposed to be the medium of transportation, apparently must be given up,[1] because all experiments fail to show any relative motion between it and the transmitting and receiving bodies. Radiant energy, therefore, if it exists at all as a separate entity, may be assumed to travel free in space independently of a medium. The energy from which the radiant energy is derived is, however, always associated with a vehicle, and this vehicle is some physical object or body. For instance, the energy of electric waves arises from the electric energy of the wireless telegraph antenna, or the Hertz oscillator; that of light and heat from the energy of the incandescent or hot body. Once separated from the source, in general, it does not return to it, or returns only after a long time and by a circuitous path. This makes the distinction between the behavior of an open and a closed electrical circuit. In the open circuit, a large part of the energy is lost by the circuit at each oscillation and never returns to it; whereas in the closed circuit, if we neglect the energy which is lost through ohmic resistance, there is practically no loss of energy during an oscillation, energy that disappears in one form reappearing in another. Such an oscillator as this, Fleming has called a *magnetic oscillator*.[2]

According to Maxwell's theory of electromagnetism, although the energy of the source is always *associated* with a physical body it is not contained wholly within this body, but largely in the space outside of it. For instance, the energy of every cubic centimeter of the space about a Hertz oscillator, when it is charged, and before the oscillation begins, is equal to $E^2/8\pi$, where E is the mean strength of the electric field within the cubic centimeter. To find the total energy of the oscillator $E^2/8\pi$ must be integrated throughout all space. According to Maxwell's theory then the energy of this oscillator resides not within the material of which the oscillator is made, *or even on its surface*, but in the space surrounding it.

[1] Planck, Acht Vorlesungen über theoretische Physik, pp. 116, 117.

[2] Electric Wave Telegraphy, 2d edition, pp. 413–416.

The difference between the conception of the energy of a moving body and the conception of electrical energy according to Maxwell's theory may be shown by an illustration. If a pipe through which a steady current of water is flowing is buried in a wall, unless the water makes a noise in flowing, we have no means at present known to us of detecting its existence. On the other hand, if a wire carrying a steady electric current is buried in the wall the existence of the current can be detected, at any point within a reasonable distance, by the behavior of a magnet. From this fact comes the assumption that the condition of the space *surrounding* the wire is that which produces the energy of the current in the wire.

The question which I shall consider in this paper is: What do we know about *radiant energy* and the way that it disappears at one point and appears at another? In the case of the radiation of waves of sound from a material body, such as the sounding board of a piano, we know that the motion of the sounding board is communicated to the surrounding air and travels out in all directions according to well-known mechanical laws. What we want to know is: How do the waves of light, heat, and electricity travel in space, why are they given off by one oscillator and received by another, and how do they go from one point to another?

§ 2. On the Conception of Energy.

The belief in the real existence of energy seems to be almost the only thing which has emerged from the recent discussions of physical principles unchanged, and yet the conception of energy is after all essentially a mathematical conception. The energy of a body, or of a system of bodies, measures its power of doing work. Mechanical energy is expressed either as one half of mass times velocity squared, or as force times distance. It is not in any sense a primitive or fundamental conception. The savage is familiar with the ideas of time, distance and force, but has no conception of energy. Indeed we have only to go back three centuries to find a hopeless confusion of the ideas of force and energy. Energy is a concept of the highly trained mathematical mind. It is a mathematical function of the same kind as entropy[1] and action. To state the principle of the conservation of energy is to state a mathematical relation governing physical phenomena.

Mach says: "Energy and entropy are *metrical* notions."[2] Also, "If we estimate every change of physical condition by the *mechanical work* which can be performed upon the disappearance of that condition, and call this measure *energy*, then we can measure all physical changes of condition, no matter how different they may be with the same common measure, and say: *the sum total of all energy remains constant.*"[3]

[1] For a statement of the parallelism between energy and entropy see Planck, *Physikalische Zeitschrift*, Jahrgang 13, pp. 168, 169, 1912.

[2] On the Principle of the Conservation of Energy, Popular Scientific Lectures, Open Court Publishing Co., p. 178.

[3] Ibid., p. 164.

The principle of the conservation of energy is a principle of equivalence rather than of equality. It states that when a given amount of mechanical work is done a given amount of heat or electrical energy will appear. The equivalence of heat and electrical energy is known only through their respective equivalence to mechanical work. In fact, when we show that every time we do 4.2 joules of work we obtain 1 calorie of heat, we do not prove that 1 calorie is equal to 4.2 joules, but simply that they are *equivalent* quantities of energy.

Energy appears to me to have no real existence independently of physical objects. Knowledge of the universe comes to each individual only through his senses, and by means of sense impressions. Physical bodies or objects are concepts based upon groups of sense impressions.[1] A physical object is that which appeals to my senses through its attributes. I can feel, touch, taste or see it. A chair, a table or a piece of sugar has a real existence. For the sake of brevity, a thing which has real existence may be called an *entity*. The energy of a body is defined as the power or ability of the body to do work, and is measured by the work done. The ability of a body to do work is a measure of its state or condition. Energy therefore is a measure of the condition of a body. Velocity and momentum are also measures of the condition of a body, and not entities.

Time and space, also, are not entities, but are the modes under which we perceive things apart. Motion is a combination of space with time and is also a mode of perception.[2]

Matter is a generic or group name for all physical objects. It is not in itself an entity but is the group name for all entities.

It is impossible to conceive of energy apart from an object. It is a measure of the physical condition of a body or of a system of bodies, and a measure of a condition is certainly not an entity.

Another property of energy which seems to me to show that it has no existence independently of bodies is that of its complete relativity. For instance, when two elastic bodies are moving with different speeds if they come together they can do work on each other and therefore have kinetic energy with respect to each other. If, on the other hand, they are both moving with the same speed they can never come together and do work on each other and consequently have no relative kinetic energy, however fast they may be moving.

What do we mean, then, when we say that radiant energy is propagated through space? We simply mean that some of the energy of a certain body disappears, and that an equal or less amount of energy appears in another body at a later time. How it goes from one place to the other, or even if it goes at all, we do not know; we simply know that it disappears and reappears according to certain laws which are known as the wave theory of light. If space were empty there would be no light. The phenomena of light can only exist where there are bodies to emit it, and bodies to receive it.

[1] Pearson, Grammar of Science, pp. 178, 281.
[2] Ibid., pp. 156, 191, 193, 293, 240.

One result of this view of the matter is that the principle of the conservation of energy cannot be extended to empty space; it must be limited in its application to actual physical bodies. If we extend it to empty space, we assume that energy is an entity and can exist independently of physical objects. This we have seen is not true. If energy cannot exist by itself in free space many of the conclusions of the modern German school are invalidated, for they are based on this assumption.

It will, of course, be possible to retain the *mathematical* expression for the energy of space, considering the energy of space simply as a mathematical concept, not expressing any reality, and using it simply in order that energy may be a continuous function of space, just as we use magnetic or electric induction, in order to have a continuous function of the field with which to operate. From this point of view, Poynting's theorem, expressing the radiant vector in terms of the strength of the electric and magnetic fields, still has a meaning, although a purely mathematical one.

A difficulty in connection with the conception of the existence of energy in free space independently of matter arises when we consider the absorption of energy by matter. If *matter* and *energy* are *independent entities* of *different kinds*, it is impossible to conceive of their having any effect upon each other. But matter does acquire energy; therefore energy cannot be an entity existing independently of matter.

§3. On the Different Types of Electrical Oscillators.

Electrical oscillators as they occur in nature are of many different forms. The best known of all of them, the Hertz oscillator, consists of two conducting spheres connected by a conducting rod. In such an oscillator, to a first approximation, the capacity of the system can be taken as equal to one half of the capacity of one of the spheres, and its inductance to that of the rod. The time rate of radiation of energy from a Hertz oscillator is given by the formula

$$\frac{dW}{dt} = \tfrac{2}{3}c\frac{d^2(el)}{dt^2},$$

where W is the energy of the oscillator, c is the velocity of light, e is the charge on one sphere, and l is the distance between the spheres. The product of e and l is called the *electric moment* of the oscillator. The rate of radiation of energy by a Hertz oscillator is therefore proportional to the acceleration of its moment.

Planck[1] and Lorentz[2] have based their electrical theories of radiation solely upon an electronic oscillator of this type. The Hertz oscillator is, however, only one of a large number of different types of oscillators. There are oscillators that are entirely closed; there are those that are partially closed, such as are formed by the plates of a condenser; there is the linear oscillator, the spherical oscillator,

[1] Planck, Wärmestrahlung.
[2] H. A. Lorentz, The Theory of Electrons.

the bi-spherical oscillator, and an unlimited number of others. It is, of course, possible that the action of all oscillators may be reduced to that of the electric doublet, or to that of the electron vibrating about a mean position, but it seems to me to be very improbable.

Of especial interest are a class of little known oscillators consisting of *closed* conductors, the disturbance taking place within the space enclosed by the conductor, and not exterior to it.[1] Of such a character are the electrical oscillations within tubes which have been investigated by Larmor,[2] Lang,[3] Rayleigh,[4] Drude,[5] Weber,[6] Kalähne[7] and others. The theory developed by Weber gives the wave-length of the fundamental vibration within a straight tube as equal to 3.415 times the radius. For the closed conductor we may have a straight tube closed at the ends, a closed circular tube, or a cavity of any shape completely closed by a conductor. If the electrical disturbance takes place entirely *within* the cavity of the conductor, and there is no disturbance outside of the conductor, we shall have what may be called an *interior* system. Systems oscillating electrically may be divided into *interior* and *exterior* systems, according as the disturbance takes place within a conducting surface or outside of it.

An electrical system may pass by gradual steps from a closed into an open system. For instance, if we have a straight conducting tube closed at the ends, and an oscillation taking place within it, we may imagine that a small hole is made in the walls of the tube. Speaking in the language of the Maxwell theory we may then say that a small part of the radiant energy within the tube will pass out of it, and it will no longer be a closed system. The fraction of the total energy issuing can be made as large as is desired by increasing the size of the hole.

If the walls of a closed system are perfectly conducting, after the state of radiation has once been set up and a steady state has been reached it will continue for ever if the volume and shape of the closed surface remain unchanged.

It is remarkable that if the walls of a closed system are perfectly conducting, and it is at rest, there will be no way in which a human being who is outside of the system can detect the existence of the electrical oscillations within the system.

On the other hand, Hasenöhrl[8] has shown that it follows as a result of Maxwell's theory that if such a system is set into motion the radiant energy, E, within it will produce an apparent increase of mass equal to $8/3\ E/c^2$ grams.

[1] When I say that an electrical disturbance takes place at a point in space, I simply mean that if an electric charge is placed at that point it will be acted upon by a force. I do not mean to imply that any disturbance can exist at a point independently of a charge. In fact, I would say, that if there is no physical object at the point, there can be no disturbance at the point.

[2] *Proc. Lond. Math. Soc.*, 26, 119, 1894.

[3] *Sitz. Wien. Akad.*, II (a), 104, 980, 1895; 105, 253, 1896; *Wied. Ann.*, 57, 430, 1896.

[4] *Phil. Mag.*, 43, 125–132, 1897.

[5] *Wied. Ann.*, 65, 481, 1898.

[6] *Wied. Ann.*, 8, 743, 1902.

[7] *Wied. Ann.*, 18, 92–127, 1905; 19, 80–115, 1906.

[8] *Annalen der Physik*, Bd. 15, pp. 344–370, 1904.

The presence of the radiant energy, therefore, cannot be detected by an outside observer, at all, if the system is at rest. If it is set into motion it will be evident only as apparent inertia, and cannot be distinguished from the true mass of the system, unless the true mass is already known.

This discussion of possible forms of electrical systems, suggests that particles of matter, be they atoms or electrons, may in some cases be *closed* electrical systems having many degrees of freedom, none of which would become evident until the closed nature of the system had in some way been broken down.

If it could be shown that all matter consisted of various arrangements and combinations of an ultimate unit, such as the electron, it might be possible to reduce all forms of radiation to that of the electron, and to regard the electron as a very minute Hertz oscillator. It appears to me, however, that the conception of an ultimate unit is impossible.

It is in the first place impossible to conceive of a body so small that when placed under a microscope it cannot be magnified to any desired extent, and after it is magnified it will be impossible to conceive of it having no structure. If it has structure, it must have still smaller parts of which it is built up. If it is impossible for the mind to grasp the idea of an *ultimate* unit of matter, it seems to me to be doubtful if a satisfactory theory of radiation can be built upon it.

It is possible that all forms of matter may be found to be related, and that the phenomena of discharges in rarified gases, and of radioactivity, may be due to the behavior of minute particles of matter carrying electric charges, but it is improbable that these particles are all of the same size and that they represent an ultimate element of mass. It must be remembered that when dealing with enormously large numbers of minute particles the methods are statistical ones, and only mean values can be obtained.

§ 4. The Principle of Relativity.

If a medium for the transportation of radiant energy actually exists it must either remain at rest while the earth moves through it, or else it must be, to a greater or less degree, carried along with the earth.

The phenomenon of aberration discovered by Bradley[1] in 1728 would seem to show that the ether, if it exists, remains at rest in space, and that the earth moves through it. For Bradley found that the apparent position of a star in the sky depended upon the ratio of the speed of the earth in its orbit around the sun to the velocity of light. In fact he found that if v is the component of the earth's velocity at right angles to the line joining the earth to the star, the angular aberration, α, is given by

$$\tan \alpha = \frac{v}{c}.$$

From his observations he found that the maximum displacement of a star from its mean position, due to aberration, was 20.44 seconds.

[1] *Phil. Trans.*, 35, p. 637, 1728.

On the other hand, Michelson and Morley[1] using the most refined methods of experimentation were unable to detect any relative motion between the earth and the ether. Their method was, using the interferometer, to send a ray of light a fixed distance, first in the direction of the orbital motion of the earth, and then in the opposite direction and try to find a difference in time for the two paths. If the ether exists and is stationary and the velocity of light is independent of the velocity of the source, it is evident that such a difference of time would exist. This difference of time would produce a shifting of the fringes in the interferometer. But no such shifting could be found. Many other experiments both optical and electrical,[2] among which may be mentioned those of Mascart,[3] Rayleigh,[4] Brace,[5] Lodge,[6] and Trouton and Noble,[7] have failed to show any relative motion.

The assumption of the existence of an ether therefore puts us on the horns of a dilemma. The phenomenon of aberration indicates that the ether is stationary and does not move with the earth, necessitating an ether *drift*, but when we make experiments to detect this drift we are unable to obtain any evidences of it although there are many possible experimental ways in which it could be detected if it existed.

To explain the failure of the Michelson and Morley experiment to detect this drift, FitzGerald[8] and Lorentz[9] suggested, in 1892, that a body might be shortened in the direction in which it moved.

A theory which will account for the experimental facts was proposed by Einstein[10] in 1905 and has been called the principle of relativity.

The principle of relativity rests upon two postulates; the first being that all motion is relative, man having no means of detecting absolute motion or absolute rest in space; and the second that the velocity of light is independent of the motion of the emitting or receiving bodies, and is a universal constant. The first postulate, so far as the motion of material bodies is concerned, has been recognized as true since Newton's time, and is now extended by the Principle of Relativity so as also to cover the motion of material bodies with respect to space: this extension being the result of the many efforts which have been made in recent years to detect relative motion between the earth and the hypothetical ether.

These two postulates when subjected to analysis show that, if we *assume*

[1] *Am. Jour. Sci.*, 34, p. 333, 1887.
[2] Whittaker, History of the Theories of Æther and Electricity, 1910, pp. 411–448.
[3] *Annales de l'Ec. Norm.*, (2), 1, 1872, p. 157.
[4] *Phil. Mag.*, 4, p. 215, 1902.
[5] *Phil. Mag.*, Sept., 1905.
[6] *Phil. Trans.*, 184, p. 727, 1893; 189, p. 149, 1897.
[7] *Phil. Trans.*, 202, p. 165, 1903.
[8] See Lodge, *Nature*, 46, p. 165, 1892.
[9] *Verslagen d. Kon. Ak. van Wetenschappen*, 3, p. 74, 1892.
[10] *Annalen der Physik*, Bd. 17, pp. 891–921, 1905. See also: *Jahrbuch der Radioaktivität*, 4, 411–462, 1907.

the Principles of the Conservation of Momentum, and the Conservation of Energy to be always true for material bodies, when we make measurements of the physical state of a moving body, the units of length, time and mass are not constant but vary with its speed.

The principle[1] shows that a second measured by a stationary clock bears to a second measured by a clock moving with a velocity v, the ratio

$$\sqrt{1-\left(\frac{v^2}{c^2}\right)}:1$$

where c is the velocity of light.

The unit of length in a moving system is shortened in the ratio

$$\sqrt{1-\left(\frac{v^2}{c^2}\right)}:1.$$

Consequently any moving body, to a stationary observer, appears to be shortened in the direction of its motion.

If m is the mass of a body in motion and m_0 is its mass at rest, the mass of the moving body will be apparently greater than that of the body at rest in the ratio

$$\frac{m}{m_0}=\frac{1}{\sqrt{1-\left(\frac{v^2}{c^2}\right)}}.$$

The experiments of Kauffmann[2] and Bucherer[3] on the mass of charged particles moving in a vacuum tube seem to confirm this increase of mass with velocity although as More[4] has pointed out all that was really determined in these experiments was the decrease of the ratio e/m as the velocity increased and the results might be explained by assuming that e, the charge, was not constant as is usually assumed but decreased with the velocity.

The kinetic energy, E, of a moving mass, m_0, is equal to $\frac{1}{2}m_0v^2$ according to the Newtonian mechanics: according to the principle of relativity it appears to be greater than this and is given by

$$E=m_0c^2\left(\frac{1}{\sqrt{1-\left(\frac{v^2}{c^2}\right)}}-1\right).$$

According to this theory, therefore, if the velocity of a body could be made equal to that of light its kinetic energy would appear to be infinite.

It is, I think, evident that the principle of relativity occupies an important place in the theory of radiation. In the first place it discards the ether, and in

[1] For a clear statement of this principle see Lewis and Tolman, *Phil. Mag.*, October, 1909.
[2] *Annalen der Physik*, 19, p. 487, 1906.
[3] *Phys. Zeitschr.*, 9, p. 755, 1908; *Ber. d. deutsch. Phys. Ges.*, 6, p. 688, 1908.
[4] *Phil. Mag.*, February, 1911, p. 216.

the second place it gives to the quantity, c, which we call the velocity of light, certain very peculiar properties.

If the principle of relativity be adopted as a working hypothesis we have three alternatives as to the nature of radiant energy: it must exist independently in space; it must be carried by small particles of matter, after the manner of the corpuscular theory of light; or else it has no real existence in space. I think I have shown by my discussion of the nature of energy and of Einstein's light quantum theory, in the next section, that the first alternative is untenable. The phenomena of the dispersion, interference and polarization of light appear to preclude the hypothesis of its transmission by small particles, and we are therefore driven to the last alternative that energy has no real existence in space.

If c is a universal constant, as is asusmed by the relativity theory, and measurements of it will always have the same value whatever the motion of the observer, it cannot be of the nature of a mechanical velocity. This I think is also indicated by the fact that it is equal to the ratio of the electrostatic to the electromagnetic unit of quantity.

If the second postulate of relativity is true it appears to me that the reciprocal of the so-called velocity of light must be of the nature of a *time reaction constant*. That is, a light disturbance originating at one point in space becomes evident at another point at a distance s at a time t given by

$$t = ks$$

where $k = 1/c$. The reaction time, t, according to this view is proportional to s. Since nearly all actions and reactions of matter, including thermal, chemical, electrical, and possibly gravitational actions require a certain time to act even if the distances by which they are separated are very small, this view of the reciprocal of c does not seem to me to be very unreasonable.

Since the second postulate of relativity says that the apparent velocity of light is independent of the motion of the source and of the observer, and the first postulate says that any motion between the source and the observer is relative, the first postulate resolves itself into the statement that the velocity of light is independent of the velocity of the source. This is the form in which Einstein originally gave it. He called it the principle of the constancy of light velocity.

If the velocity of light did depend on the velocity of the source, and the two velocities were additive, it would explain all the phenomena which the principle of relativity explains, but there is no evidence that the velocity of light does depend upon the velocity of the source. No decisive evidence appears to be at hand at present to determine this point, but what evidence we do have seems to show that the velocity of light is independent of the source.[1]

[1] Tolman, The Second Postulate of Relativity, *Physical Review*, 31, 26–40, 1910; Whittaker, History of the Theories of the Æther, pp. 413–415; Lorentz, *Physikalische Zeitschrift*, 11, pp. 1239, 1240, 1910.

§ 5. On Planck's Theory of Elementary Quantities of Energy.

In 1900, Planck,[1] starting with the assumption that the sources of radiant energy are electric oscillators within the atom, proposed the remarkable theory that these oscillators contained heat energy only in multiples of an elementary quantity which he called a *quantum* and designated by ϵ. Thus, in a given volume of gas, some of the molecules would contain an amount of energy equal to 1ϵ; some, to 2ϵ; others, to 3ϵ, and so on. He assumed that these energy quanta would be distributed among the molecules according to the law of probabilities. He further assumed that the magnitude of the quantum varied with the frequency, ν, of the oscillator, and indeed was proportional to it, so that we would have

$$\epsilon = h\nu,$$

where h is a universal constant. Experiment shows that

$$h = 6.548 \times 10^{-27} \text{ ergs} \times \text{seconds}.$$

It will be observed that h has the dimensions of energy multiplied by time, and that therefore it has the dimensions of action. Planck called it the *Wirkungsquantum*, or the action quantity. It might be called in English the action constant.

The result of making the magnitude of the quantum proportional to the frequency of the elementary oscillator, is that for very high frequencies the quantum becomes very large, and for very low frequencies, very small. But according to the law of probabilities there can only be a few of these very large and very small quanta distributed among the molecules. This means that the energy will be so distributed among the oscillators that those of mean frequencies will have most of it, while those of high or low frequencies will have only a small part of it. This is found by experiment to be actually the case.

Proceeding on the assumptions stated, Planck found an expression for the mean energy, U, of an oscillator, namely

$$U = \frac{h\nu}{e^{h\nu/kT} - 1}, \tag{1}$$

where ν is the frequency of the oscillator, T is its absolute temperature, and k is the universal gas constant. Experiment shows that

$$k = 1.346 \times 10^{-16} \text{ ergs/degrees}.$$

Equation (1) can be contrasted with the expression for the mean kinetic energy of a molecule of a gas given by the kinetic theory of gases:

$$U = \tfrac{3}{2}kT. \tag{2}$$

[1] *Verh. d. Deutsch. Phys. Gesell.*, 2, pp. 237–245, 1900; *Annalen der Physik*, 4, pp. 553–566, 1901.

By combining equation (1) with an expression (3) for the mean intensity of radiation, for the steady state, R_ν, resulting from an oscillator of mean energy, U, and frequency, ν,

$$R_\nu = \frac{\nu^2}{c^2} U, \tag{3}$$

Planck obtained a formula for the energy density, u, in a space completely surrounded by black walls,

$$u = \frac{8\pi h\nu^3}{c^3} \frac{1}{e^{h\nu/kT} - 1}. \tag{4}$$

One of the results of Planck's theory is that an elementary oscillator can only radiate energy in multiples of a definite unit ϵ, for if it did otherwise its total energy would not remain always equal to a multiple of ϵ.

The strongest evidence in favor of this remarkable theory is that it gives a theory of the radiation of a black body which agrees with the results of experiment. Other theories such as that of Lorentz[1] based upon the Theory of Electrons, and the Rayleigh-Jeans[2] theory based upon the Theorem of the Equipartition of Energy are incomplete, being true only for the long wave-lengths of the spectrum.

Another remarkable development of this theory is its application by Nernst[3] to the theory of specific heats. In this domain it gives results which are in wonderful accord with the results of experiment.

Combined with the gas laws it also gives values for the mass and charge of the electron which agree closely with experimental values.

In his earlier development of the theory, Planck assumed that both the emission and absorption of energy by the oscillators could only take place in definite multiples of the quantum, ϵ. In his more recent papers, however, he has modified his views, and he now assumes that an oscillator can *emit* energy only in definite multiples of ϵ, but that it can *absorb* it *continuously*.[4] He also points out in his recent writings that this discontinuous emission can only be conceived of as taking place in an oscillating system, and cannot be conceived of as taking place when a body is moving continuously in a straight line.

He also draws attention to the fact that it is the elements of disturbance, rather than the elements of energy, which are distributed according to the law of probabilities,[5] and that h, the action constant, is introduced by the necessity of using a statistical method.

[1] Lorentz, Theory of Electrons, pp. 80–90.

[2] Rayleigh, *Nature*, vol. 72, pp. 54, 55, 1905; Jeans, *Philosophical Magazine*, vol. 10, pp. 91–98, 1905.

[3] *Zeitschr. f. Elektrochemie*, Bd. 17, pp. 265–275, 1911.

[4] *Annalen der Physik*, Bd. 37, pp. 142–656, 1912; *Physikalische Zeitschrift*, Jahrg. 13, pp. 174, 175, 1912.

[5] Larmor, *Proc. Roy. Soc.*, vol. 83, A, pp. 82–95, 1909.

Einstein[1] has gone much farther than Planck and has proposed the theory that energy exists in free space, unassociated with matter, in certain definite units, these units being the quanta of Planck, now no longer associated with matter, but projected into free space.

He says: "The undulatory theory of light operating with continuous space functions has served excellently for the representation of pure optical phenomena and will indeed never be replaced by another theory. It is however to be noted that optical observations are concerned with time-mean values, and not with momentary values, and it is conceivable that, in spite of the complete confirmation of the theory of diffraction, reflection, refraction, dispersion, etc., by experiment, the theory of light operating with continuous space functions leads to a contradiction of experience when one applies it to the phenomena of light production and light transformation."

"It appears to me, indeed, that the observations of black radiation, photoluminescence, the excitation of cathode rays by ultraviolet light and those groups of phenomena which are concerned with the production and transformation of light, can be better understood on the assumption that the energy of light is discontinuously distributed in space. According to this assumption the energy of a ray of light issuing from a point is not distributed continuously over a larger and larger space but consists of an endless number of elements of energy (*Energiequanten*) localized in points of space, each one of which moves without being divided and can only be excited or absorbed as a whole."

This hypothesis of Einstein that energy exists in discrete elementary quantities in free space has been called the light-quantum hypothesis, and may be distinguished by this name from Planck's energy-quantum hypothesis. It differs from Planck's hypothesis in that, in Planck's hypothesis, the energy-quanta exist only in association with matter. Planck[2] himself does not accept the light-quantum hypothesis of Einstein.

Certain well-known experimental results can, however, conveniently be explained by Einstein's hypothesis.[3]

For instance, Stokes' law that the light given out by a phosphorescent body is as a rule of lower frequency, ν_2, than that, ν_1, of the exciting light, can be explained by supposing that only *one* quantum goes to excite an oscillator. We would then have

$$h\nu_2 \lessgtr h\nu_1$$

$$\nu_2 \lessgtr \nu_1.$$

The exceptions to Stokes' law can be explained by assuming that in such cases or two or more quanta are absorbed by each elementary oscillator.

[1] *Annalen der Physik*, Bd. 17, pp. 132–148, 1905; Bd. 20, pp. 199–206, 1906; Bd. 22, 180–190, 1907; *Physikalische Zeitschrift*, Jahrg. 10, pp. 185–193, 817–826, 1909.

[2] *Annalen der Physik*, Bd. 31, pp. 761–763, 1910.

[3] Lorentz, *Physikalische Zeitschrift*, Jahrg. 11, pp. 351, 352; 1249, 1250, 1910.

Again, the *velocity* of the electrons emitted by a highly polished metal plate under the action of ultraviolet light is found to depend upon the frequency and not upon the intensity of the exciting light. And on the other hand, the *number* of the electrons emitted depends upon the intensity of the exciting light. These results can be explained if we again assume that the energy of each electron comes from a single impinging quantum. For then, with monochromatic light of a given frequency, each quantum would impart to each electron a definite velocity which would depend only upon the given frequency.

Again, since the energy of a light quantum is directly proportional to the frequency of the light, we see why, according to Einstein's theory, light of the lower frequencies would not produce the photoelectric effect, the energy of a single quantum not being great enough. Lorentz[1] gives the following illustration. If we take for ultraviolet light

$$\nu = 1.03 \times 10^{15}$$

we will have for the energy of a quantum of ultraviolet light

$$\epsilon = h\nu = 6.7 \times 10^{-12} \text{ erg.}$$

According to Lenard, the energy of the emitted electron is equal to

$$3 \times 10^{-13} \text{ erg.}$$

An ultraviolet quantum then has enough energy to produce the observed velocity of the electron, and also enough to do whatever work is necessary to set it free.

Einstein's hypothesis can also be used to explain the peculiar results obtained by Stark[2] for the Doppler effect in canal rays. Since the particles in a beam of canal rays have many velocities, varying from 0 to a certain maximum value, it is to be expected that if the light emitted by the moving particles is observed in a spectroscope, in the direction of their motion, a characteristic line of the gas will be spread out, in a band, towards the violet end of the spectrum, the band beginning at that point in the spectrum where the characteristic line normally exists. Stark, however, found that the band did not begin at this point but at some distance to the right of it, and that it had two maxima of brightness. The appearance of the band and the positions of the maxima can be explained if we assume that the particles radiate light energy only in multiples of a quantum. No particle would then radiate energy unless upon a collision with a molecule its kinetic energy was great enough so that it could emit one or more quanta. The first maximum would then correspond to a velocity which would make the kinetic energy great enough to produce an emission of one quantum, and the second maximum to a velocity which would make the kinetic energy great enough to produce an emission of two quanta. Stark found that the ratio of the distances of the

[1] *Loc. cit.*, p. 1249.

[2] *Physikalische Zeitschrift*, Jahrg. 9, p. 767, 1908.

maxima from the characteristic line was of the value that would be expected on this theory.

Notwithstanding the fact that Einstein's theory can be used to explain these experimental results, I do not think that his light-quantum hypothesis is admissible. From my point of view energy has no existence independently of matter, and therefore certainly cannot be propagated through space, apart from matter, in discrete quantities. It appears to me, however, to be quite possible that the experimental results just described may be explained on Planck's quantum hypothesis which involves the disappearance of energy from matter in discrete quantities.

Lorentz[1] has indicated very clearly the difficulties and absurdities into which the light-quantum hypothesis would lead us. For instance, he shows that since 2 million interference maxima can be obtained for yellow light, a quantum must in some cases be at least a meter long. Also to fulfil the requirements of the theory of diffraction for optical instruments it must be as wide as the objective of our largest telescope. Consequently, under certain circumstances, the quantum would be quite bulky!

Finally, the question arises does Planck's energy-quantum hypothesis hold for *electric oscillations*, that is for those oscillations whose periods are longer than those of the infrared? In this case, since an energy quantum is equal to $h\nu$, and ν is small, the quantum would become very small. It is to be noted that the sole confirmation of his hypothesis lies in his application of it to the statistical theory of the elementary oscillator. His theory of radiation is a statistical one derived on the assumption that the radiating body is made up of a very large number of discrete elements. In order that there shall be a large number of these elements they must be small, and if they are small their frequencies must be high. There is, to my mind, therefore, no evidence that Planck's energy quantum hypothesis holds for electric oscillations beyond the infra-red.

Summary.

1. Energy has no real existence independently of matter, and cannot exist free in space.

2. The types of electrical oscillators are very numerous and it is improbable that the Hertz oscillator can be considered the sole elementary type.

3. The so-called velocity of light is not a quantity of the nature of a mechanical velocity. Its reciprocal may, perhaps, be regarded as of the nature of a time reaction constant.

4. Planck's energy-quantum hypothesis is a statistical hypothesis and probably only true for the short waves of heat and light, and not for long electric waves.

5. Einstein's hypothesis of the light-quantum is untenable because it is based on the assumption that energy can exist free in space.

[1] *Loc. cit.*, pp. 1249, 1250.

The History and Zoological Position of the Albino Rat

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PHILADELPHIA

1912

THE HISTORY AND ZOOLOGICAL POSITION OF THE ALBINO RAT.

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The common rats in the United States live usually in close association with man. They have been introduced from Europe. There are two species; *Mus rattus*, with its gray variety *Mus rattus alexandrinus*, and *Mus norvegicus*, the Norway rat, our present common form. The fourth form, the albino rat (*Mus norvegicus albinus*), derived from *Mus norvegicus*, is known only as a domesticated strain.

Mus norvegicus probably originated in central Asia, where an indigenous form, *Mus humiliatus*, may represent the parent stock, while *Mus rattus* seems to be native in Persia and India.

Both species have migrated westward across Europe and to the Americas within the last seven or eight hundred years. The migration of *Mus rattus* preceded that of *Mus norvegicus* by some six hundred years, but as the Norway rat is the more ferocious and powerful species, it has become dominant wherever it has followed the black rat.

Nevertheless in many places where the black rat is said to have been exterminated, it still survives in small numbers.

The early history of these migrations is of necessity vague and incomplete and even in the later times when dates are given for the appearance of the Norway rat in various countries, it must be remembered that these might have been present for considerable periods without appearing in numbers sufficient to cause comment.

The Greek and Roman writers before the present era do not seem to have been acquainted with the rat, which therefore, even if present, was probably not abundant at that time on the north shores of the Mediterranean.

The first reference to the rat in natural history appears about 220 A. D. in *De Natura Animalium* by Claudius Ælianus.

In this case we assume that *Mus rattus* is the form meant. Probably as far back as the Völkerwanderung (400–1100 A. D.) and later as the result of opening trade routes with the east during the crusades, the black rat reached Europe. It is reported to have arrived there as early as the twelfth century (Leunis, '83) or the thirteenth century (Thomas, '86), being mentioned by Albertus Magnus—the *doctor universalis*—(1193–1280). It was of course probably present for some time before it was noted.

Thus the European rat of the middle ages, the rat of the legends, of the "Pied Piper" (1284), of the great plagues (before 1700) and of the early anathemas against vermin, was *Mus rattus*.

The species first brought to America on the ships of the very early explorers was *Mus rattus alexandrinus*.

Concerning its arrival there is little exact information. The earliest date given is 1548 and later we have one instance of a plague of these rats in the Bermudas in 1615.

Mus rattus, the black rat, is the only form recognized by Linnæus in his *Fauna Suecica*, 1746, and the only form given in his *Systema*, 1766. It does not concern us here to follow further the history of *Mus rattus* in the United States.

Returning to *Mus norvegicus*—the species at present dominant in China, Japan, seaboard India, western Europe and temperate North America—it may be stated that no significance can be attached to the specific name, *norvegicus*, given by Erxleben. The historical record of the movements of this species, though by no means accurate, has the virtue of being recent.

Gesner (*Historia animalium*, 1620) is said to allude to the form now called *norvegicus*, but had apparently never seen it himself.

Authorities agree that the Norway rat invaded Europe from the east early in the eighteenth century, when it was observed in large numbers crossing the Volga in the Russian province of Astrakhan. Pallas ('31) gives 1727 as the year of this migration In view of other dates, this can hardly be the date of the first invasion. The Norway rat reached England—by ships—about 1728–1730, and was soon designated the "Hanover" rat by those who wished to connect the misfortunes of the country with the recently established house of Hanover. There is, however, no reason to suppose that the Norway rat had yet reached Germany, and the name has a political rather than a scientific interest.

In 1750 the Norway rats are reported to have reached eastern Prussia and in 1753 they were noticed in Paris. Their early distribution to other localities in Europe need not be recounted, but there is evidence that they spread rapidly and soon displaced more or less completely the *Mus rattus* which had preceded them.

The arrival of the Norway rat on the north Atlantic seaboard of the United States is variously given as 1755 (Zuschlag, p. 26) and 1775 (Lantz, '09). Although the exact date is hardly important for our present purpose, yet on the other hand, exact dates are always of value as matters of record, and I wish to call the attention of those who may be interested to the importance of any references which might be obtained from colonial diaries or letters in the last half of the eighteenth century. Such references would be very welcome.

This brief account suffices to show that the Norway rat was brought to the United States about the middle of the eighteenth century or a little later. *Mus rattus* was already in possession, but in the course of the years, how rapidly we do not know, the Norway rat became the dominant form, at least in the northern latitudes of this country, moving along the trade routes to all points which furnish a continuous food supply, and a moderate temperature.

The Norway rat shares with the black rat the reputation of being a great

destroyer of grain and other foods and a prime carrier of the bubonic plague. Because of this latter failing, both are now being hunted the world over.

Our interest in the Norway rat in the present instance however is not due to its economic or hygienic importance, but to the fact that the common albino rat (*M. n. albinus*) kept as a pet or laboratory animal, and concerning which we desire all possible information, is a strain of the Norway rat.

This is shown by the physical characters of the albino (blood crystals, shape of skull, etc.) and the fact that the two forms interbreed freely. Concerning the place and time of origin of the albino strain, there is little information at hand. Allusions to albino rats before the time when the Norway rat appeared in Europe clearly show that there must have been an albino strain of *Mus rattus*. The only trace of this strain which has been found during the last twenty or thirty years is a single skin in the American Museum of Natural History in New York (Allen).

By some curious slip, many of the natural histories and books of reference speak of the existing albino as an albino of *Mus rattus*. This of course is not correct, but owing to the confusion thus introduced, it is difficult to trace the history of the present form.

We do not know whether it had a single origin or several, or whether the colonies found in Europe are directly related to those found here.

It may be possible at some future time to solve this problem of origin, but at the moment there is nothing to be said from the side of historical records.

Judging from the way in which the albinos of other species arise, we may safely assume that the present strain is derived from one or more albino mutants or sports, to use the older term. These must have been captured and the albino descendents protected and kept as pets, as there is nowhere to be found an established colony of albinos living in open competition with the common Norways or with forms of *Mus rattus*, but all of the colonies are maintained practically under conditions of domestication.

Within a few weeks, Dr. Hatai at the Wistar Institute has obtained from Norway rats bred in captivity for several generations, two litters consisting mostly of normal grays but one of which contained three albinos and the other, one. This appears to be an unique instance of the production of albino rats under laboratory conditions.

Having followed the history of the albino rat—such as it is—and commented on its zoological position, it remains to say a few words first about the effect of domestication on the albino, and second, about the albino strain from a stock-breeding standpoint.

Effect of Domestication.—The albino rat differs from the wild Norway by not attaining so large a size at maturity, by having become slightly shorter and by having lost about 13 per cent. in the relative weight of its central nervous system (brain and spinal cord).

There are other differences in the various viscera, which, though not so conspicuous, may be biologically of great importance. Further, the albino has become docile and easy to handle and has very largely lost its habit of gnawing.

We are inclined to regard these alterations as the result of domestication, and one prime experiment which needs to be made in this connection is to allow the albinos to run wild for some years and observe such changes as may occur. For this we need the use of an island where the albinos may be set free, thus giving the opportunity for following the effects on them of a return to the wild life.

As has been said, the origin of the albino strain must have been from one or more mutants or sports, and groups of albinos were probably obtained not only by the direct pairing of two mutants, but by the method we now designate as "extraction." Thus if the hybrids from gray and albino parents are bred together, the albino character appears in the next generation in a given proportion of the young. Albinos thus obtained are called "extracted albinos."

While all such albinos breed true as to color, the composition of the germ elements or gametes is undoubtedly different among them in accordance with their ancestry. This can be illustrated by the studies on coat color.

The current analysis of color development in animals leads to the view that it depends on a chromogen—or color-producing substance—a color ferment (or tyrosinase) which by its action on the chromogen gives rise to the pigment proper and a so-called color pattern factor—which determines the distribution of the pigment—as a rule in accordance with some general scheme.

It appears very probable (Saunders) that the albino lacks only the color ferment. Thus the albino, according to this view, still carries the chromogen and also the color pattern factor.

It has been noted that this last may even show itself in the albino by the character and distribution of the white hairs (Mudge).

The gametic dissimilarity of various albinos in respect to color is further shown by the fact that in breeding tests (Mudge) with pigmented mates albinos extracted from ancestors with characteristic differences in pigmentation will reveal their origin by producing characteristically pigmented descendents, the markings of which can be predicted. So much for the case of color. Other characters, however, may be studied in the same way.

In the case of some other characters, such as body length or brain weight, Dr. Hatai has been able to show that if these depend on a very large number of determinants, it may be possible to retain the theory of alternate inheritance in relation to them, even in the face of the fact that the descendents apparently show a blended inheritance without evident segregation.

Whether such characters are to be regarded as of the same class as coat color, is a problem by itself. What we are immediately concerned with is the gametic composition of the general population of the albino rats as they appear in our colony to-day.

As the colonies stand, the albinos are not a strictly homogeneous or homozygous population from the standpoint of color, or from the standpoint of many other characters. The differences are, however, not sharply marked, and sometimes do not reveal themselves except under very special conditions. Nevertheless, the albino rats do not represent a pure strain in the present sense of that term. Indeed it is not possible to obtain a pure strain in any mammal, as it can only follow from reproduction by budding or in forms capable of self-fertilization.

This completes the survey of rather an interesting case of the distribution of a small mammal and its modifications in captivity. In closing I wish to emphasize by repetition the points on which information is specially desired. These are as follows:

1. Colonial records of the appearance of the Norway rat on the eastern seaboard of North America. These are most likely to be found from 1750 to 1775.
2. The earliest date at which the albino rat was observed in the United States.
3. The discovery of a living specimen of an albino of *Mus rattus*.
4. News of some conveniently placed island with a continuous food supply where the albinos might be turned loose in order to watch the effects on them of a really wild life—especially the effect on the growth of the nervous system.

The Gorgonians of the Brazilian Coast

BY

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PLATES XXIX–XXXV

PHILADELPHIA
1912

THE GORGONIANS OF THE BRAZILIAN COAST.

By Addison E. Verrill.

The following article is based largely on collections made by Professor C. F. Hartt, during an expedition to Brazil in 1867, and others made by his associates, about 1876, while he was engaged upon the Geological Survey of Brazil. Most of the later collections were made by Mr. Richard Rathbun. Some were made by Mr. J. C. Branner. The source of the specimens studied is given under each species.

I have also been able to add descriptions and figures of the spicules of some long known but poorly described species, prepared from the type specimens in European museums by Prof. Albert Kölliker and sent to me by him in 1867.

Hitherto the Alcyonarian fauna of Brazil has been very little studied. Although a few species were briefly described by Lamarck, Milne-Edwards, Ehrenberg, and Gray, they are isolated examples.

The only paper devoted especially to the Brazilian Anthozoa, including the Gorgonacea, was published by the writer in 1868.[1] In that paper five species of Gorgonians were described.

The Challenger Expedition dredged a few deep-water species off the coast, and two shallow water species, enumerated below, were obtained off Bahia. These were well described and figured. The deep-water species are not included in this paper except as mentioned here and on p. 380.

The Hassler Expedition, 1872, also dredged off Brazil, a few species that have not yet been described, mostly from rather deep water.

One is a red and yellow species of *Evacis*,[2] allied to *E. solitaria* (Pourt.). It was from off Bahia in 200 fathoms.

A slender species of *Primnoëlla*, belonging to the Primnoidæ, was dredged off La Plata in 44 fathoms. These have been described and figured for the Report on the "Blake" Alcyonaria, soon to be published.

The present paper is intended to include only the shallow water species of Gorgonacea. Probably many more remain to be discovered on the extensive coast of Brazil, whenever systematic dredging is undertaken at moderate depths. Probably a rich and almost unknown fauna will be found in 40 to 150 fathoms,

[1] Notice of the Corals and Echinoderms collected by Prof. C. F. Hartt, at the Abrolhos Reefs, Province of Bahia, Brazil, 1867. *Trans. Conn. Acad. Science*, I, pp. 351–371, Plate IV, 1868.

[2] This is a new genus of Muriceidæ with large, thick, external plates, but with unarmed calicles. The type is *E. rosea* V., a handsome, branched, red, West Indian species with large, red, elliptical plates. *E. solitaria* (P.) has much smaller external plates. Many other species occur in the West Indian deep water fauna.

as in the West Indies, where about 100 new species of Alcyonaria were found in such depths.

About 24 species and named varieties are now recorded, but a few are very superficially known. About 19 appear to be valid species, sufficiently described.

Very few Alcyonaria of other subordinal groups have been recorded from Brazil. The Pennatulacea are represented in the Bay of Rio de Janeiro by two species or varieties of *Renilla* (*R. violacea* Q. and G., and *R. danæ* Verrill, 1864), and by *Stylatula braziliensis* (Gray) from off Cape Frio.[1]

The Telestidæ are represented by *Telesto rupicola* (F. Müller).

The apparent absence of representatives of the Alcyonacea is a remarkable feature of the Brazilian fauna. They are also few in the West Indies and at Panama, while in the Indo-Pacific fauna they are very abundant, large, and diversified.

Professor C. F. Hartt mentions (op. cit., 1870) a soft "nodose alcyonarian" as growing on the masonry of the Custom House Dock at Rio de Janeiro and on rocks near Guarapary. No specimens were in the collection sent to me. Perhaps it was *Telesto rupicola* Müll.

I am indebted to my son, Mr. Alpheus Hyatt Verrill, for the photographs and accurate drawings that illustrate this article.

PECULIARITIES OF THE FAUNA.

It is doubtful if any Brazilian species has been found elsewhere. Some have formerly been recorded, probably erroneously, as from the West Indies: for instance, *Phyllogorgia quercifolia*, one of the most common Brazilian species, but not obtained in the West Indies by modern collectors. Others have been erroneously identified with similar West Indian species without sufficient comparison.

The affinities of the genera are, however, entirely with those of the West Indies. This applies particularly to the genus *Plexaurella*, which has several related species in each fauna and is rarely found elsewhere; and to the restricted genus *Gorgonia*, which has several West Indian species and three from Brazil, but is not known to occur in any other fauna. The foliaceous species here referred to *Phyllogorgia* are probably all Brazilian, but they are closely allied to typical *Gorgonia*, although so different in appearance.

The three Brazilian species of *Muricea* form a little group by themselves, but they are more related to West Indian species than to those of other regions.

The total absence of many very common shallow water West Indian genera is very striking, and though it may be due to some extent to scanty collecting, this can hardly explain the general fact. Among such lacking genera are *Plexaura*, *Plexauropsis*, typical *Eunicea*, *Euniceopsis*, etc.

A remarkable peculiarity has been observed in the chemical composition of the axis of several species of otherwise typical *Gorgonia* and *Leptogorgia*.

[1] Kölliker, Pennatul., II, p. 227, pl. XVII, fig. 139, 1870.

Instead of being entirely horn-like and flexible, as in the West Indian species, they have the axis more rigid and partially calcareous, so that it effervesces feebly in acids, as in some *Gorgonellidæ*. This shows that this character alone is scarcely sufficient to separate the families. In fact, some of the Brazilian species of *Leptogorgia* might be considered as connecting links between the families, in this respect.

Another interesting morphological feature has been found to be highly developed in all the several Brazilian species of *Plexaurella*. Though not confined to the Brazilian species, they show it more prominently developed than in others. Reference is made to the elaborate system of tubules permeating the cœnenchyma in all directions and rendering it cellular, some of them connecting with the exterior by special pores, evidently to permit the free discharge or intake of water during rapid contraction and expansion of the large polyps, as well as for distribution of nourishment. (See below, under subfamily *Plexaurellinæ*, Plate XXXV, figures 14, 15.)

GEOGRAPHICAL DISTRIBUTION.

Most of the species here included occur in the coral-reef region of Brazil, extending from somewhat north of Pernambuco, or about S. Lat. 7°, to the Abrolhos Reefs and Porto Seguro, or to about 18° S. Lat. But some of the gorgonias, like some of the corals, have a wider range, extending southward beyond the actual coral-reefs to Victoria Bay, and even to Cape Frio, about S. Lat. 23. Such species, therefore, have a range of about 16 degrees or over 1,000 miles. Among those having a wide range are *Phyllogorgia quercifolia*, which is known to extend from Bahia to Cape Frio; *Muricea humilis*, ranging at least from Parahiba to Guarapary; and *Plexaurella cylindrica*, from Bahia to Cape Frio.

Very likely all the reef-inhabiting species extend at least as far north and south as do the coral reefs.[1]

Unfortunately we know almost nothing of the corals and gorgonians inhabiting the long stretch of coast between Pernambuco and the Antilles, a distance of over 2,000 miles. Therefore it is impossible to say whether the coral fauna of the Antilles extends to the southward of the Orinoco River at any point. Nor is it possible to say, at present, whether any of the corals and gorgonians extend on the northeastern coast of Brazil, beyond Maranhao, from whence we now have two new species of gorgonians not known from any other place.

From south of Cape Frio we have two species of *Leptogorgia* in the Bay of Rio de Janeiro. This genus, in other regions also, is apt to extend into the temperate waters beyond the areas of coral reefs. One gorgonian species, *Plexaurella obesa*, comes from Fernando des Norhona.

[1] For descriptions of the Brazilian coral reefs, see C. F. Hartt, Geology and Physical Geography of Brazil, pp. 190–214, Boston, 1870. Also, R. Rathbun, *Proc. Boston Soc. Nat. Hist.*, XX, pp. 39–41, 1878, and *Amer. Naturalist*, XIII, pp. 539-551, 1879. Also J. D. Dana, Corals and Coral Islands, ed. 3, pp. 113, 140, 352, 1890.

As in the case of the reef-corals, it is remarkable that any of the species should be so closely allied to the West Indian species as we actually find them to be, considering the great distance separating the two faunæ and the apparently impassable barriers caused by the waters of the Amazon and Orinoco. As in the case of the reef-corals[1] the relationship may be due to the conditions existing in earlier geological periods, with a different coast line, and probably before the Amazon and Orinoco existed in their present condition, and the Valley of the Amazon was covered by the sea, as it appears to have been in the Cretaceous.

However, there are many cases of identical species among Echinodermata and Crustacea, ranging from the reef regions of Brazil to the West Indies, indicating that those groups and others have had less difficulty in migrating, or else that they have changed less rapidly.

It is not possible to believe that the migration has been southward from the Antilles with the existing ocean currents flowing northward along the entire northern coast of Brazil for 2,000 miles. Moreover, the freshening of the waters for many miles beyond the mouths of the Amazon and Orinoco would probably prove fatal to the delicate, free-swimming larvæ of gorgonians and corals, thus preventing migrations in either direction along extensive regions of the coast.

So far as known, the larvæ of gorgonians remain but a short time in the free-swimming stage, and many, indeed, are viviparous. As in the case of the corals, it is more probable that, in the instances of allied species, the Brazilian fauna is the older, and that at some remote period migration to the Antilles was possible.

The relations of the Brazilian gorgonians to those of West Africa and the Pacific are very remote.

Family MURICEIDÆ (Gray) Verrill, emended.

Primnoaceæ (*pars*) Kölliker, Icones Hist., 1865, p. 135.
Muriceidæ Verrill, Bull. Mus. Comp. Zool., vol. XI, p. 30, 1883. Wright and Studer, Voy. Chall., XXXI, p. 92, 1889. Nutting, Monograph III, Siboga Exped., 1910.

Armed or armored Gorgonaceæ with exposed external spicules, the outer generally larger than the inner ones. Calicles usually prominent, commonly with the margin armed with spinules; walls armed or unarmed, often plated.

Cœnenchyma often spinulose, sometimes covered with a mosaic of thick plates. Tentacles generally have opercular spicules on their bases.

As here limited several genera usually referred to this family are excluded, especially those that have an external layer of very small, short, granule-like spicules, as in *Astrogorgia* and *Heterogorgia*, or an external layer of small clubs perpendicular to the surface, as in *Bebryce* and *Eunicella*, (see under *Plexauridæ*). *Anthogorgia*, *Stenogorgia*, and *Filigella* are also excluded.

The only shallow-water Brazilian genus is *Muricea*. The three species known are not very nearly related to any of the several West Indian species, but form a group by themselves.

[1] For a discussion of the distribution of the Brazilian reef-corals and their relation to the West Indian species, see Verrill, *Trans. Conn. Acad. Sci.*, XI, pp. 63–205, 25 plates, 1901, "Variations and Nomenclature of Bermudian, West Indian and Brazilian Coral Faunæ."

In 200 fathoms, off Bahia, the Hassler Expedition dredged a red and yellow variegated species of *Evacis*, a plated genus that includes *E. solitaria* (Pourt.).

Muricea humilis (Edw.) Verrill.

Gorgonia citrina Lamk., Hist., vol. II, p. 317; ed. 2, p. 494 (*non* Esper).
Eunicea citrina Val., Comptes-rendus, XLI, p. 12, 1855.
Eunicea humilis M.-Edw., Corall., vol. I, p. 149, pl. B2, fig. 1, 1857. Verrill, Trans. Conn. Acad., vol. I, p. 360, pl. IV, figs. 4–4b, 1868. Hartt, Geology of Brazil, pp. 62, 179, 210, 1870.

Plate XXIX, figures 1, 1a (branchlet and spicules of No. 1515b, in natural colors). Plate XXXII, figures 4, 5 (branchlets of the same). Plate XXXV, figure 2 (calicles of the same). Text cut, No. 1 (spicules).

Variety humilis.

The best grown and probably the most normal specimens have the crowded branches more or less clavate, and mostly 4 to 6 mm. in diameter distally, more slender at the base. The branches that are crowded and less exposed are smaller. The calicles are a little prominent and nariform. The color is lemon-yellow to sulphur-yellow, often with a tinge of purple, due to some small purple spicules at the surface.

It forms close clumps, from 100 to 130 mm. high and about as broad. The larger spicules are clear sulphur-yellow and diversified in form. Part are stout, regular, acute, evenly warted spindles; some are more slender; many, especially those near the surface, have large, conical spinules on the outer side or near one end; others are warted clubs with the larger end spinose with sharp spinules; many are irregular spinose spicules. The superficial purple spicules are slender, strongly warted spindles.

The larger regularly warted spindles measure 0.69×0.18; 0.58×0.13; 0.51×0.18; 0.49×0.14; 0.44×0.15; slender spindles, 0.46×0.09; club-spindles, 0.40×0.17; one-sided spinose spindles, 0.67×0.18; 0.31×0.12; spinose clubs, 0.31×0.16; 0.18×0.14; ellipsoids, 0.26×0.18; small purple spindles, 0.22×0.07; 0.21×0.08 mm.

Abrolhos Reefs, abundant, coll. C. F. Hartt, 1867. Nos. 1515a, b. Common at Bahia and at Port Seguro in shallow water; sometimes in tide-pools. Parahyba do Norte, R. Rathbun, 1876. No. 4564. Extends southward to Guarapary. (Hartt.)

Variety mutans, nov.

This variety agrees with the normal form in color and mode of branching. The branches are rather more slender, mostly 3 to 4 mm. in diameter. The calicles change their form or character in different parts.

Near the bases of the larger branches they are a little prominent, conical or verruciform, with a small round terminal orifice. On some of the less exposed branches they are scarcely raised above the general surface. Distally, on the more exposed branchlets, they partly become low verruciform with the aperture looking upward; partly slightly nariform, while some remain as mere pores.

The spicules agree essentially with those of the normal variety. The larger specimen (No. 1515c) is 125 mm. high and 130 mm. broad.

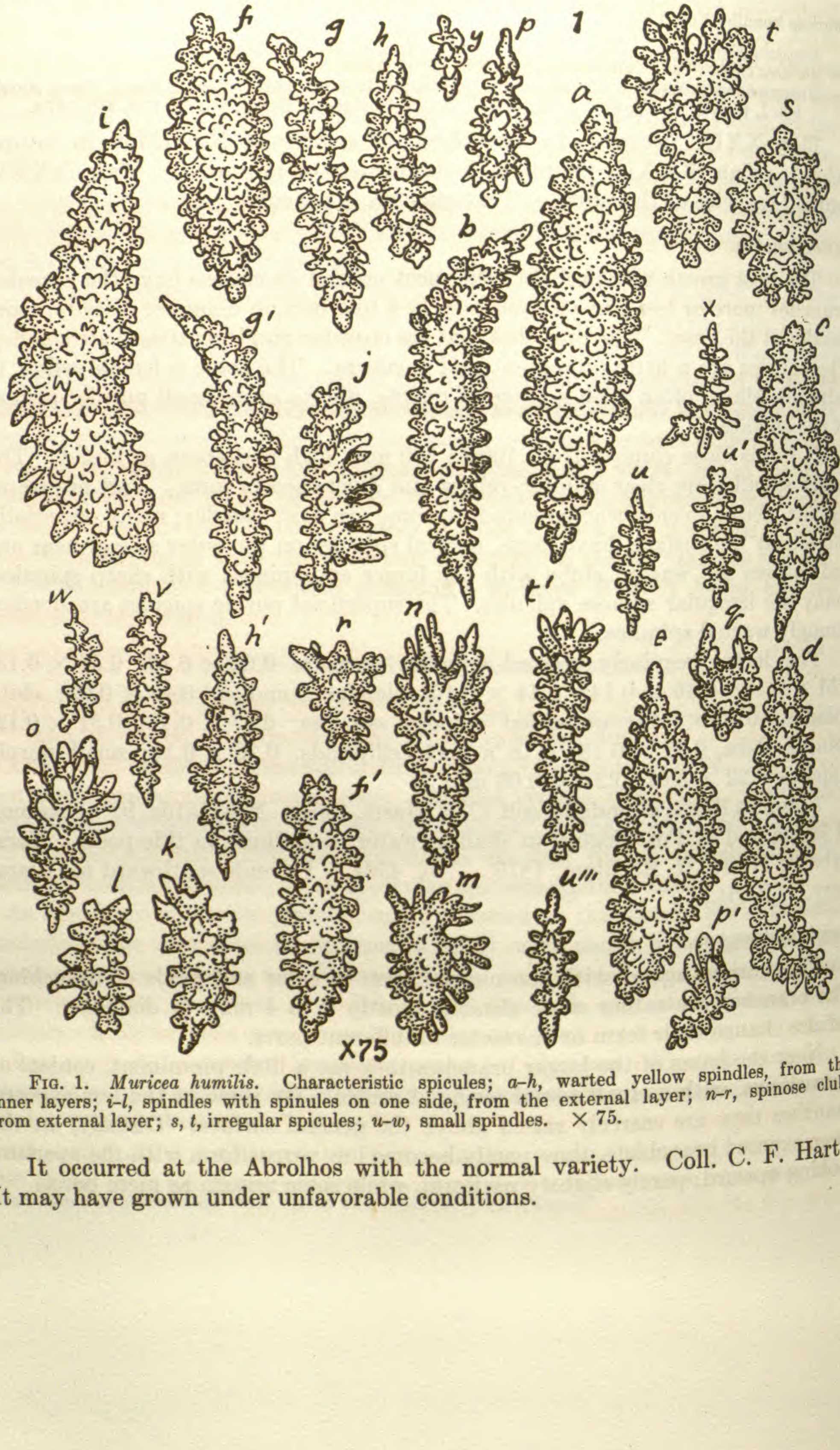

FIG. 1. *Muricea humilis.* Characteristic spicules; *a–h*, warted yellow spindles, from the inner layers; *i–l*, spindles with spinules on one side, from the external layer; *n–r*, spinose clubs from external layer; *s*, *t*, irregular spicules; *u–w*, small spindles. × 75.

It occurred at the Abrolhos with the normal variety. Coll. C. F. Hartt. It may have grown under unfavorable conditions.

Variety macra, nov.

This variety looks like a distinct species superficially. It is much more slender, more upright, and more loosely branched than the other varieties. The stalk is unbranched near the base; branching is at first subdichotomous. The branchlets are short and arise irregularly pinnately; they are slender and terete. The calicles are small, on many parts they are obsolete or represented only by small pores; in other places they are slightly raised verrucæ, opening upward; rarely they become subnariform. It appears as if partly starved by unfavorable conditions; hence the name.

The color is pale yellow, tinged with purple by superficial purple spicules. The inner spicules are yellowish white and purple. In form and structure they are the same as those of the normal variety.

Total height, 115 mm.; breadth, 60 mm.; diameter of branchlets, 2 to 3 mm.

Abrolhos Reefs, with the normal form. Coll. C. F. Hartt, 1867. No. 1515d.

Muricea acropora Verrill.

Plate XXXII, figure 3 (small branch of No. 4510). Plate XXXV, figures 1, 1a (spicules of the same).

The coral of the type is a densely branched fruticose clump, consisting of six main branches, arising close to the base, and giving off on all sides numerous short branchlets and branches, so closely placed that they are mostly nearly or quite in contact. The small branches and branchlets are so graded that each principal branch forms a tapering or thrysiform cluster of branchlets.

The terminal branchlets are mostly from 10 to 15 mm. in length and about 3.5 to 4.5 mm. in diameter. Total height, 100 mm.; breadth, about 120 mm. Color pale yellow.

The calicles are small, prominent, crowded, and mostly divergent. Where best developed they are nariform, with a small, prominent, obtuse or subacute lower lip. The aperture is small and directed upward, and the walls are rather thick. In some other places the lower lip is obsolete and the aperture round and small.

The surface is rough with the sharp spinules of the outer spicules. The spicules are nearly white, very roughly spinulated, and diversified in form. Some of the larger ones from the interior are rather slender, regular, acute spindles, covered with prominent branched or spinulated warts; others are bent and often unequal-ended spindles. Many of the larger spindles from the exterior have one or several conical or irregular outgrowths on one side, which subdivide or give rise to several strong, sharp, simple spinules projecting at the surface. Others are elongated and roughly warted clubs, with a group of stout, conical spinules on the larger end.

The regular warted spindles measure 0.85×0.17; 0.68×0.15; 0.60×0.13; 0.56×0.21; one-sided spinose spindles, 0.79×0.24; 0.75×0.22; 0.70×0.27; 0.57×0.21; spinose spindles with branched outgrowths on one side (fig. 1a, m), 0.79×0.34; spinose clubs, 0.70×0.21; 0.65×0.36 mm.

Mar Grande, Bahia. Coll. Richard Rathbun. Exped. C. F. Hartt. Type, No. 4510.

The mode of branching and the forms of the branches and calicles are so similar to certain slender-branched Oriental species of corals of the genus *Acropora* (formerly *Madrepora*) as to suggest the name.

Muricea bicolor Wright and Studer.

Voy. Chall., vol. XXXI, p. 134, pl. XXIII, fig. 11 (calicles), Plate XXV, figure 8.

This species is evidently nearly allied to the preceding, but it is more loosely branched, with larger branches. The calicles also differ in form, and the spinulation of the spicules is finer and more complex. Those of the inner layer are violet-color.

It was dredged off Bahia, Brazil, in 10 to 20 fathoms by the "Challenger."

Family PRIMNOIDÆ Gray (emended).

Primnoadæ Gray, op. cit., p. 285, 1857.

This family, which is partial to deep water, is not represented in our littoral Brazilian collections, but some species have been found in moderate depths off the coast of Brazil and farther south.

The "Challenger" took *Primnoëlla distans* Studer, an Australian species, off Pernambuco, in 120 to 200 fathoms. The Hassler Expedition, 1872, dredged *Primnoëlla nitida* V., a slender, unarmed, diffusely branching species with polished calicle-scales, imbricated in four or five rows, in 44 fathoms, off La Plata.

The "Challenger" also dredged *P. magellanica* Studer and *P. murrayi* W. and S., both in 600 fathoms, off Montevideo.

No doubt these and other species of the family live at moderate depths off the Brazilian coast.

The "Challenger" also dredged *Stenella johnsoni* W. and S., off Ascension I., in 420 fathoms; and *S. acanthia* W. and S., off La Plata, in 600 fathoms.

Family PLEXAURIDÆ Gray.

Plexauridæ Gray, Ann. and Mag. Nat. Hist., ser. 3, vol. IV, p. 442, 1859.
Plexauridæ Verrill (*pars*), Proc. Essex Inst., vol. IV, pp. 148, 186, 1865; and vol. VI, p. 41, 1869. Trans. Conn. Acad. Sci., vol. I, p. 413, 1868–1869. Wright and Studer, op. cit., 1889, p. 135. Nutting, Siboga Exped., Monog. XIII, b4, 1910.
Euniceidæ Kölliker, Icones Histiol., II, p. 137, 1865.
Plexauridæ Verrill, Bull. Mus. Comp. Zool., vol. XI, p. 39, 1883; The Bermuda Is., Part V, Trans. Conn. Acad. Sci., vol. XII, p. 258, 1907.

Unarmed and unarmored Gorgonacea usually having a thick cœnenchyma. Axis is not jointed, commonly branched. It may be entirely horn-like or partially calcified in some genera.

Surface of cœnenchyma is not spinose. External spicules are smaller than the inner ones and commonly form a special coating of small, club-shaped, spheroidal, or granule-like spicules of various forms. Surface is often covered with a thin membranous coating, concealing the spicules. Inner spicules are often large, mostly spindles, double-spindles and crossés, without complex forms.

Calicles may be more or less prominent or wholly immersed in the cœnenchyma. They are usually placed on all sides of the branches. Tentacles are usually retractile; they may have opercular spicules in chevrons, or may be destitute of spicules.

Nutrient or peraxial longitudinal canals are usually equal, forming a circle around the axis.

This family is found in the shallow waters of all tropical and subtropical seas; rarely in deep water.

The family is here extended to include certain genera commonly referred to the Muriceidæ and Gorgonidæ; such as *Bebryce, Eunicella, Heterogorgia, Stenogorgia,* etc.

Most of these have a well-defined layer of small differentiated spicules, characteristic of this family, and have the calicinal walls and margins unarmed, or but slightly armed with small, simple spicules.

For these rather aberrant genera I propose to establish two subfamilies: *Bebrycinæ,* to include *Bebryce* and *Eunicella,* characterized by having a close pavement-like external layer of small club-shaped spicules standing perpendicularly to the surface.

Stenogorginæ, characterized by having a thin cœnenchyma, composed of simple spindles, with or without an external layer of small granule-like spicules, and having the spindles of the calicle-walls usually arranged in chevrons distally. Tentacles usually with spicules in chevrons, retractile or not so, often forming a large exsert anthocodium.

This subfamily will include *Stenogorgia, Heterogorgia, Psammogorgia, Astrogorgia, Filigella,* and several other genera.

Heterogorgia V. has been entirely misunderstood by Nutting and some other writers. Its larger interior spicules are all simple warted spindles. Its surface has a layer of small spicules of varied forms. The type is *H. verrucosa* V., of Panama Bay.

Astrogorgia V. has also been misunderstood. It has an outer layer of small, short spicules with larger inner spindles, arranged in chevrons on the calicles. Its most important feature is the presence of very small siphonozoids on and between the calicles, each surrounded by a circle or rosette of small petal-like white plates. The type is *A. sinensis* V., 1867.

Another subfamily, *Plexaurellinæ,* may be recognized to include *Plexaurella, Euplexaura,* and allied genera, in which the axis is partially calcified, with strands of calcium carbonate. The cœnenchyma is thick, "suberous," made up of small spindles, crosses, and related forms, and everywhere permeated by tubules running in all directions, some of them terminating in external pores, rendering it very cellular.

The subfamily *Plexaurinæ* will then contain the more typical genera, such as *Plexaura, Eunicea, Euniceopsis, Pseudoplexaura,* etc.

In this group the axis is generally horn-like, the cœnenchyma is thick, usually

with small spinose or foliated clubs in the external layer and with larger, simple spindles in the deeper layers.

For descriptions and figures of most of the genera above named, with good figures of their spicules, see Verrill, *Trans. Conn. Acad. Sci.*, vol. XII, pp. 302–315, 1870, with plates.[1]

PLEXAURA Lamouroux, Polyp. Flex., pp. 448–451, 1816.

The generic type should be taken as the common West Indian species, *P. homomalla*, by elimination.

Seven species were given by Lamouroux. The first three now belong to *Plexaurella;* the fourth is indeterminable; the fifth is *Suberogorgia suberosa;* the sixth is *P. homomalla;* the seventh, *P. olivacea*, is imperfectly known.

Subfamily **PLEXAURELLINÆ** Verrill, nov.

PLEXAURELLA Kölliker.

Plexaurella Kölliker, Icones Histiolog., II, p. 138, 1865. Wright and Studer, op. cit., 1869, p. 140. Verrill, The Bermuda Islands, Part V, Trans. Conn. Acad. Sci., vol. XII, p. 310 [p. 266], 1907.

Plexauridæ having a thick, porous or subcancellate cœnenchyma, everywhere between the tubules, supported by relatively small warted spicules, consisting mostly of spindles, double-spindles, crosses, and unevenly twinned forms; with some small, short, double-heads and double-rosettes, especially in the denser surface layer. Axis more or less calcareous, the calcium carbonate in strands. Tentacles wholly retractile. Calicles usually immersed or only slightly raised, sometimes prominent, often bilabiate.

In transverse and longitudinal sections the cœnenchyma is seen to be permeated by small, anastomosing canals or tubules, running in all directions, some connecting with the polyp-cavities, others with the exterior by small pores. Between their walls the small supporting spicules are abundant and irregularly placed. See Plate XXXV, figs. 12–15.

The minute external pores of this network of tubules terminate in small pits and probably function as siphonozoöids, to regulate the supply of water in the tubules, allowing it to escape freely during the powerful contraction of the large polyps. Probably the thickness of the cœnenchyma can be made much greater in life by the water entering the tubules and causing turgescence of the tissues, while the polyps are expanded.

In the related Oriental genus, *Astrogorgia* V. (*A. sinensis*), similar pores exist, of larger size and more specialized, each being surrounded by a rosette of small

[1] By an unfortunate error of the printer in making up the plates of the work cited above, four cuts, representing the spicules of four species, were transposed. Therefore the explanation of the plates should be changed: Plate XXXVa, fig. 4, should be Plate XXXVIa, fig. 4; Plate XXXVIa, fig. 3, should be XXXVIb, fig. 3; XXXVIa, fig. 4, should be XXXVa, fig. 4; XXXVIb, fig. 3, should be XXXVIa, fig. 3. Corresponding references to these figures should be changed in the text, under *Plexaura flavida*, p. 305; *Pseudoplexaura crassa*, p. 307; and *Euniceopsis grandis*, p. 373; and *P. esperi*, p. 305.

plates. In this case they seem to be very simple siphonozoöids. In *Plexaurella* they may be only a more rudimentary or degenerate variety, without mesenteries.

To determine whether they have a distinct zoöidal structure would require specimens carefully hardened and prepared in alcohol, such as I have not seen.

The present writer first determined the zoöidal nature of the external pores in *Renilla*, in 1864 (Revis. Polyps, p. 12), and in several other *Pennatulacea* and in *Sarcophytum*, in 1865, and subsequently in various other genera.

They are rare in *Gorgonacea*, but are well developed in *Paragorgia*. They exist in *Iridogorgia*, and some other genera of deep-sea Chrysogorgidæ, and in *Anthomastus*, etc. Those of *Astrogorgia* have not been hitherto mentioned. (See also Kölliker, Pennatuliden, I, p. 37, 1870.)

The most obvious distinctive characters for this subfamily are the small sizes of the spicules and the unusual abundance of regular and irregular crosses or twinned forms among the spicules. These are often among the larger and more conspicuous forms. The axis contains fusiform strands of calcium carbonate, so abundant that it effervesces freely in hydrochloric acid.

This genus is unusually well developed on the Brazilian coast and in the West Indies.

Subgenus **PSEUDEUNICEA** nov. Type, *P. grandiflora* V.

Most of the Brazilian species belong to typical *Plexaurella*. A single species differs sufficiently to be regarded as representing a subgeneric group. Its principal characteristic is the large, prominent, exsert calicles, with the aperture bilabiate. In this respect it resembles certain West Indian species of *Eunicea*, but the spicules are like those of typical *Plexaurella*, with which it also agrees in the tubules permeating the cœnenchyma and having external openings.

The prominence of the calicles cannot be regarded as of very great importance in this group, for *P. verrucosa*, which usually has them verruciform, sometimes so contracts that they scarcely rise above the level of the cœnenchyma. The amount of elevation is also quite variable in *P. dichotoma* of the West Indies and Bermuda, according to the suddenness of killing; those killed quickly by sudden immersion in some reagents may die before much contraction can take place.

Plexaurella obesa Verrill, sp. nov.

Plate XXXI, figure 3 (general figure of No. 4509, reduced). Plate XXXII, figure 9 (calicles enlarged). Plate XXXIV, figure 6 (spicules of the same).

Coral dichotomous, with few very stout, elongated, obtuse branches, of which there are only four in the type. The branches are much thicker than the main stem. They increase gradually in size from the base for a short distance and then become cylindric, or they may be somewhat flattened. The tips are obtuse or abruptly rounded.

Total height, 240 mm.; breadth, 70 mm.; length of longest branch, 150 mm.; diameter in middle, 22 mm.; diameter of stem, 8 to 12 mm.

The calicles are rather large, irregularly scattered, mostly separated by intervals equal to about twice the diameter of the apertures. Many are not at all raised above the cœnenchyma; others have a slightly raised, thickened margin, and a few form low verrucæ. The apertures in the dry specimens are mostly partially open, about 1 mm. in diameter. The majority are elliptical or oval; many are roundish; some crescent-shaped, some are mere slits; others are nearly or quite closed, showing a mere punctate aperture, or none at all.

The cœnenchyma is nearly smooth, very thick, hard and firm, composed of vast numbers of small spicules, with still smaller ones at the surface. In some places there are rather deep, irregular grooves and wrinkles, both longitudinal and oblique, sometimes forming polygonal areas, enclosing several calicles.

In tangential sections the calicles are larger and round, about 1.5 mm. in diameter, not crowded. The tubules of the cœnenchyma are smaller and less distinct than in the allied species, while the intervening substance is filled with larger and rougher spicules that tend to obscure them. The exterior pores are minute, sunken in pits, and obscured by the irregular, rough, granule-like spicules.

Color, in alcohol, light brownish yellow; pale buff when dry. Axis in the branches hard and black.

The spicules are larger and stouter with coarser warts than in the other species. The larger ones are stout, obtuse and subacute double-spindles and unevenly developed crosses or twin-spicules. They are pretty evenly covered with spaced, rough warts. The regular crosses are large and stout, with thick, conical rays, evenly warted. Many irregular twinned spicules occur.

The larger double-spindles measure 0.53 × 0.15; 0.54 × 0.16; 0.39 × 0.15; 0.42 × 0.16; 0.38 × 0.22; 0.38 × 0.19; twinned spindles, 0.49 × 0.28; 0.44 × 0.27; crosses, 0.48 × 0.38 mm.

Fernando Noronha, Brazil. Coll. Mr. J. C. Branner. C. F. Hartt Exped. Type, No. 4509, Yale Museum.

Plexaurella cylindrica Verrill, sp. nov.

Plexaurella dichotoma V. (*pars*), op. cit., p. 361, pl. IV, 1868 (*non* Esper) Hartt, Geology of Brazil, pp. 62, 179, 210, 1870.

Plate XXXII, figure 7 (part of branch of No. 1597, enlarged). Plate XXXIV, figure 4 (spicules). Plate XXXV, figure 4 (spicules); 14 (tangential section).

Coral of the type rather stout, regularly dichotomous, with four, regular, thick, elongated, quickly ascending branches, not in one plane. The branches are terete, nearly cylindric, but most are slightly enlarged at the evenly rounded tips. The first division occurs close to the base; the second stage at 35 and 50 mm. higher.

Total height, 165 mm.; breadth, 55 mm.; length of longest branch, 150 mm.; diameter in middle, 10 to 11 mm.; diameter of calicles, mostly 2 mm.; of open apertures, about 1 mm.

The calicles are everywhere closely crowded and mostly in contact. They are scarcely raised above the general level, and their boundaries are defined

mainly by a slight depression where contiguous ones meet, thus forming mostly polygonal, often hexagonal outlines due to crowding.

The apertures are generally widely open, rounded or broad oval. Sometimes they are of double length and hour-glass shape, indicating instances of fissiparity.

The cœnenchyma is thick, hard, compact; the surface appears very minutely granular under a lens, due to very small, short spicules at the surface.

In tangential sections the calicles appear nearly round, numerous, the interstices usually not much exceeding the polyp-chambers. The substance of the cœnenchyma is coarser than in *P. obesa* and *P. braziliana*, and the supporting spicules larger than in the latter. The tubules are rather larger and more irregular than in the latter, and have apparently a more radial arrangement. Their external pores are minute, but easily seen, especially in little pits on the margins of the calicles.

The spicules are larger and stouter than in most other species. The larger ones are stout, regular crosses, tripartite forms, irregularly twinned spicules, and large, roughly warted spindles, sometimes with large, lateral outgrowths or incipient branches. Some regular, acute and subacute, evenly warted spindles also occur. Among the small external spindles are many double-rosettes and small crosses.

The larger double-spindles measure 0.42 × 0.14; 0.41 × 0.19; 0.39 × 0.15; 0.38 × 0.11; 0.34 × 0.15; twinned spicules and imperfect crosses, 0.43 × 0.27; 0.42 × 0.19; 0.30 × 0.19; crosses, 0.38 × 0.37; 0.34 × 0.22; 0.30 × 0.26; double-heads, 0.16 × 0.11 mm.

Albrolhos Reefs, Brazil. Prof. C. F. Hartt, coll. Type, No. 1597, Yale Museum. According to Professor Hartt this species ranges southward to Guarapary and Cape Frio.

Plexaurella braziliana Verrill, sp. nov.

Plexaurella anceps (?) Verrill, op. cit., 1868, p. 362, pl. IV, figs., 6, 6a (spicules), not of Duch. and Mich.

Plate XXXIV, figures 3, 3a (spicules of No. 1598). Plate XXXV, figure 12 (tangential section); 12a (surface); 15 (tangential section seen by transparency, × 24).

Coral tall, dichotomously branched, with the branches long and rapidly ascending, smooth and terete, blunt at tip. Total height, 290 mm.; breadth, 60 mm.; length of longest terminal branchlets, 150 to 160 mm.; diameter, 6 to 8 mm. The main stem and proximal part of the larger branches are smaller than the distal part; diameter of stem, 4 mm.

The cœnenchyma is thick and firm, nearly smooth to the eye; under a lens, minutely granular.

The calicles, as dried, are entirely immersed; the apertures are numerous, placed on all sides, in the form of mere slits or narrow ellipses or crescents, and sometimes ovate pores. They stand at all angles. In transverse sections the calicles are often close together.

In longitudinal, tangential sections the calicles are round, 0.50 to 0.75 mm. in diameter, often separated by intervals of 1 to 2 mm. or more; sometimes by only a thin septum. The intervening cœnenchyma is filled with numerous small pores and tubules, running in all directions, and separated by narrow, spiculose intervals, so that they produce a sponge-like or subcancellated structure.

Some of these tubules terminate at the outer surface in small pores, often situated in small pits, which may function as siphonozoids. The cœnenchyma between the ducts is densely filled with small spicules of various shapes. The outer thin, superficial layer is more dense and is largely made up of very small granule-like spicules in the form of heads, double-heads, double-rosettes, etc., closely packed.

The prepared spicules are smaller than in any of the preceding species of the genus. The most abundant of the larger spicules are regular strongly warted spindles and double-spindles, some rather short and blunt, others more slender and acute, and also tripartite forms and irregularly twinned spicules. The more regular crosses are not numerous, and most have rather narrow, blunt, or even clavate, often unequal rays, but some are very symmetrical.

Small spicules in the form of double-heads, double-rosettes, small crosses, etc., are very abundant.

The larger double-spindles measure 0.42 × 0.11; 0.35 × 0.14; 0.34 × 0.11; 0.31 × 0.12; 0.30 × 0.13; 0.26 × 0.11; 0.35 × 0.13; stout spindles, 0.27 × 0.11; 0.21 × 0.12; tripartite forms, 0.30 × 0.28; 0.30 × 0.20; crosses, 0.35 × 0.30; 0.34 × 0.22; 0.30 × 0.22; 0.29 × 0.26 mm.

In general external appearance this species closely resembles some of the West Indian varieties of *P. dichotoma*, but the spicules are different.[1]

Abrolhos Reefs. Coll. C. F. Hartt, 1867. Type, No. 1598.

Plexaurella pumila Verrill, sp. nov.

Plate XXXI, figure 5 (general figure of No. 4502, reduced). Plate XXXII, figure 8 (piece of a branchlet, enlarged). Plate XXXIV, figure 2 (spicules).

Coral of the type, low with short, irregular, crooked, dichotomous branches, not in a plane, forming a shrub-like tuft. The branching begins close to the base, and there is a secondary stalk with three branchlets, arising from the base. The main stalk divides at three and four stages, at intervals of about 10 to 20 mm.; often less. The longest terminal branch is 48 mm. long; most are 20 to 40 mm.; diameter, 6 to 8 mm.; total height, 95 mm.; breadth, 90 mm. The branchlets are often a little enlarged at the tips, which are bluntly rounded.

The calicles are rather large, pretty evenly disposed over the whole surface and rather closely crowded, being nearly or quite in contact in many places. They are only slightly raised, sometimes in the form of low, rounded verrucæ, but more often with merely the margin a little raised. The apertures are mostly

[1] For good figures of the spicules from the original types of *P. dichotoma* (Esper) and *P. anceps* (D. & M.) see Verrill, *Trans. Conn. Acad. Sci.*, vol. XII, pl. 36a, figs. 1, 2, 1870.

open, roundish or oval, but some are crescent-shaped or narrow slits; diameter, about 0.5 mm.

Color, in alcohol, deep yellowish brown; pale yellowish brown when dry.

The cœnenchyma is of moderate thickness, hard and firm; its surface is minutely granular, due to small, short spicules, rather loosely attached.

The larger spicules are irregular, stout, blunt, double-spindles and unequally twinned spicules, all strongly warted. The regular and nearly regular crosses are not numerous. They have rather long, often irregular, strongly warted, blunt or subacute rays. Triparted stout spicules also occur, and larger spindles, with rough lateral outgrowths. Among the small external spindles are rosettes, double-rosettes, double-heads, and small crosses.

The larger double-spindles measure 0.45 × 0.18; club-spindles, 0.36 × 0.19; twin-spindles, 0.35 × 0.19; twin-cross, 0.41 × 0.26; crosses, 0.34 × 0.33; 0.28 × 0.24; 0.18 × 0.12; tripartite forms, 0.33 × 0.23; 0.32 × 0.18; 0.26 × 0.20; double-clubs, 0.35 × 0.12; double-rosettes, 0.19 × 0.11; 0.18 × 0.12; rosettes, 0.12 × 0.11 mm.

Periperí Point, Bahia, Brazil. Coll. Richard Rathbun. Type, No. 4502, Yale Museum.

Plexaurella verrucosa Verrill, sp. nov.

Plate XXXI, figure 4 (general figure of No. 4503, reduced). Plate XXXII, figure 6 (part of a branch, enlarged). Plate XXXIV, figure 5 (spicules). Plate XXXV, figures 13, 13a (transverse and tangential sections).

Coral repeatedly dichotomously branched from close to the base. In the type the larger branches fork at four levels, producing twelve branchlets. The branches are rather long, terete or nearly so, but usually slightly enlarged at the tips, which are obtusely rounded and smoothish. Elsewhere the surface is pretty closely covered with low verruciform calicles, more regular than in most species of the genus.

Total height of the type, 245 mm.; breadth, 100 mm.; length of longest branches, 150 mm.; diameter in middle, 8 to 11 mm.; mostly about 10 mm.

The calicles are rounded, dome-shaped, or sometimes almost hemispherical. They are mostly nearly or quite in contact at their bases. Their apertures are nearly all closed so as to show only a narrow slit; some are narrow elliptical or ovate; a few are widely open, round or elliptical. In some places, near the base, the calicles are contracted to nearly a level with the cœnenchyma.

Diameter of calicles, about 2 mm.; of open apertures, about 1 mm.

The cœnenchyma is thick, fine-grained; its surface and that of the calicles is nearly smooth, appearing very minutely granular under a lens, due to great numbers of minute, short, rough spicules at the surface.

The texture is compact and firm. In tangential sections the calicle-chambers are about 1 mm. broad, rather crowded, separated by interstices often less than their diameters. The tubules are larger than in most of the other species, very

numerous, separated by thin interstices filled with very small granule-like spicules. Their external orifices are very numerous, small, but easily seen on all parts. The external layer of spicules is compact, and composed of multitudes of very small double-heads, heads, and other forms.

The axis, in the branches, is dark brown, round, slender, finely striated. The larger spicules are stout, blunt, evenly warted spindles and irregular twinned spicules. The regular crosses are of moderate size, with short blunt and warted tips. Three-rayed spicules and various irregular forms are abundant. Among the small external spicules are many rosettes, double-rosettes, double-heads, club-cones, rosette-cones, etc.

The larger double-spindles measure 0.49 × 0.19; 0.44 × 0.15; 0.38 × 0.11; 0.29 × 0.13; twinned spindles, 0.45 × 0.17; 0.38 × 0.11; crosses, 0.39 × 0.18; 0.30 × 0.22; 0.26 × 0.25; 0.23 × 0.22; 0.19 × 0.19; tripartite forms, 0.26 × 0.19; 0.26 × 0.16; 0.22 × 0.15; clubs, 0.22 × 0.11; 0.19 × 0.11; double-clubs, 0.19 × 0.14; rosettes, 0.08 × 0.08; double-rosettes, 0.16 × 0.08 mm.

Candeias, Pernambuco, Brazil. C. F. Hartt Exped. Type, No. 4503, Yale Museum.

Subgenus **PSEUDEUNICEA** V., nov. (see p. 383).

Plexaurella (Pseudeunicea) grandiflora Verrill, sp. nov.

Plate XXXI, figure 6 (general figure of No. 4501, reduced). Plate XXXII, figure 10 (calicles enlarged). Plate XXXIV, figure 1 (spicules of the same). Plate XXXV, figures 3, 3a (portions of tips of axis).

Coral stout, dichotomous from near the base. The type divides at three stages, producing seven unequal, stout branches, which quickly ascend and are separated only by narrow spaces. They lie nearly in a plane.

The branches are all stout, terete, much thicker than the main stem, straight or curved, slightly enlarged at the bluntly rounded tips, and closely covered on all sides with large, prominent, verruciform calicles, which mostly have narrow elliptical or crescent-shaped and more or less bilabiate apertures. They are occasionally wide open and roundish; in that case the calicles are nearly cylindric.

The tentacles are entirely retracted.

Total height of type, 140 mm.; breadth, 95 mm.; length of longest branchlet, 93 mm.; diameter of branchlets, in middle, 12 to 14 mm.; of stem, 9 mm.; diameter of calicles, 2.5 to 3 mm.; height the same.

Color, in alcohol, light yellowish brown; when dry yellowish gray.

The cœnenchyma is very thick, fine grained, compact; its surface is covered with minute, short spicules, looking like dust under a lens.

In tangential sections the polyp-chambers are round, close together, about 1.5 mm. in diameter. The tubules of the cœnenchyma are small and very numerous, separated by thin interstices filled with small, mostly granule-like spicules. Their external openings are minute, in small pits of the surface.

The external layer is more dense, composed largely of very small double-heads and heads.

The larger spicules are elongated and acute, pretty evenly and closely warted white spindles and double-spindles, some of them blunt or irregular. The regular four-branched crosses are relatively small and not numerous, with short, thick rays, closely covered with graded warts. There are also many crosses with two arms shorter, and some with one arm obsolete, or nearly so, forming triradiate spicules. The small external spicules are partly double-rosettes and partly close double-heads and small crosses.

The larger double-spindles measure 0.53 × 0.15; 0.40 × 0.13; 0.38 × 0.15; 0.34 × 0.12; twin-spindles, 0.48 × 0.18; crosses, 0.21 × 0.19; imperfect crosses, 0.20 × 0.12; double-rosettes, 0.15 × 0.10; 0.12 × 0.11; 0.12 × 0.10; 0.15 × 0.08; double-heads, 0.15 × 0.12; 0.12 × 0.09; heads, 0.12 × 0.11; clubs, 0.15 × 0.12 mm.

Mar Grande, Brazil. Coll. Richard Rathbun, Hartt Exped. Type, No. 4501, Yale Museum.

Subfamily **PLEXAURINÆ** Verrill, nov.

Eunicea castelnaudi M.-Edw.

Milne-Edwards, Corall., vol. I, p. 148, 1857.

Nothing is known by me of this species except the original very meager description.

It was placed by Edwards in the section of *Eunicea* having a very thick, "suberous" cœnenchyma and bilabiate apertures. The calicles are described as large and short. It is repeatedly dichotomous.

Bahia, Brazil. Coll. M. de Castelnau (M.-Edw.).

Subfamily **STENOGORGINÆ** Verrill, nov.

FILIGELLA Gray.

Gray, Annals and Mag. Nat. Hist., ser. 4, vol. II, p. 443, text-fig. 2, 1868.

According to Gray the axis is slender, terete, horny, free at both ends. Cœnenchyma is composed of a single layer of spindles and the calicles have similar spindles. They are small, verruciform. Tentacles wholly retractile.

The free condition is doubtless due to an injury and subsequent repair of the broken stem by the cœnenchyma growing over it. I have often seen the same condition in slender species of *Viminella*, etc.

The genus seems to be closely allied to *Stenogorgia*.

This genus has recently been well revised by K. Kinoshita.[1]

He secured a number of good specimens of a new Japanese species, which he described fully. He unites *Elasmogorgia* Wr. and Stud., with *Filigella*, and admits that the specimens are sometimes attached.

[1] *Journ. Col. Sci., Imp. Univ. Tokyo*, vol. 27, pp. 1–16, pl. I, II, 1909.

Filigella gracilis Gray.

Gray, op. cit., p. 443, text-fig. 2, 1868. Wright and Studer, Voy. Chall., p. 132, 1889 (no description).

This species is represented as very slender and thread-like, with the calicles alternate and far apart, low-conical, or verruciform. Distance between calicles, 1.75 inches. No other dimensions are given, but the reduced figure shows about 20 calicles. If the distance between refers to those of one row and only ten belong to a row, the length would be at least 17 inches, but this is conjectural.

Off Cape Frio, Brazil, with Pennatulacea (Gray). The type is said to have been lost.

Family GORGONIDÆ Verrill.

Gorgonidæ (restr.) Verrill, Proc. Essex Inst., Salem, Mass., vol. IV, pp. 148, 186, 1865; and vol. VI, p. 41, 1869. Trans. Conn. Acad. Science, vol. I, p. 384, 1868, 1st ed.; 1869, 2d ed. Wright and Studer, Voy. Chall., vol. XXXI, p. 146, 1889.

Unarmed Gorgonacea having the cœnenchyma and calicle-walls filled with an aggregation of very small, simple, unbranched spicules, without any very definite arrangement, and without larger spicules or spinules at the surface.

Spicules are mostly girdled double-spindles, simple spindles, double-rosettes, double-wheels, and scaphoids.

The axis is either horny or partially calcareous, without joints. It is usually variously branched, generally in a plane; branchlets anastomosing or free. It may be unbranched, long and slender.

Calicles are small, often immersed in the cœnenchyma. Tentacles are nearly always wholly retractile, often bearing small spicules in chevrons on the stems.

Adaxial nutrient canals are usually bilaterally disposed, especially in the smaller branches. There is usually a larger one at the middle line of each broad side, and a corresponding superficial groove usually shows at the surface of dried specimens.

As above defined, this family would not only include the Gorgonidæ having a horny axis, but also part, if not all, of the Gorgonellidæ, in which the axis is largely calcareous. Indeed, in my own opinion, the latter group should be considered merely a section or subfamily of Gorgonidæ, under the name *Gorgonellinæ*, or better, *Ellisellinæ*.

This view is much strengthened by the study of the Brazilian species, described below, for several of the otherwise typical species of *Gorgonia* and *Leptogorgia* are found to have the axis calcareous in a marked degree, indeed as much so as in *Gorgonella sarmentosa*, the type of *Gorgonella* and of the group called Gorgonellidæ. *G. sarmentosa* might even be considered a *Leptogorgia* with a partially calcareous axis, for the spicules are nearly as in *Leptogorgia*, as well as the calicles. Indeed, Kölliker, in his revision, placed it with the *Leptogorgia* group, as some others have done later.

Other genera of Gorgonellidæ, like *Verrucella*, *Juncella*, *Viminella*, usually

have the axis more strongly calcareous, and have slight variations in the spicules that are scarcely more than of generic value.

Gorgonia hartti Verrill, sp. nov.

Plate XXIX, figures 6, 6a (branch and spicules of No. 4554, in natural colors). Plate XXX, figure 2 (branch of same). Plate XXXIII, figure 6 (spicules of same). Plate XXXV, figure 6 (calicles of same).

Coral purplish red to blood-red, flabelliform, reticulated, with slender, slightly flattened branchlets and branches, becoming somewhat quadrangular on the larger branches, owing to the calicles being arranged mostly in four rows. The branchlets almost all anastomose, except the terminal ones. The largest specimen (No. 4553) is a broad, flabelliform specimen, 200 mm. high and 345 mm. broad, dividing into two main lobes.

Several main branches arise from close to the base and diverge radially, some giving off many branches of the third and fourth orders, which quickly become subparallel and are connected together by numerous transverse branchlets of about the same size, producing squarish, irregular, and oblong meshes, mostly 3 to 4 mm. wide. The color of this specimen is bright purplish red or nearly blood-red when wet.

The other specimen is 145 mm. high; width was about 100 mm., but about half is broken off.

The meshes are rather small, mostly from 2.5 to 4 mm., but varying from 2 to 8 mm., and sometimes more. They vary greatly in shape. Many are square; some are oblong; some triangular; but most are irregular in form. The larger branches have a somewhat radial arrangement but the small transverse branchlets often diverge at right angles, or nearly so. They often fork, or two or more may inosculate between the branchlets.

The calicles are very small, 0.3 to 0.5 mm. in diameter, rounded verruciform, or dome-shaped, as contracted. The aperture is usually entirely closed, or shows only as a minute oblong or elliptical slit, but in some cases the whitish spicules of the nearly retracted tentacles can be seen as minute white spots.

The calicles are numerous and usually form two close alternate rows on each edge of the branches and larger branchlets, giving them a more or less quadrangular form. The bases of the consecutive calicles are often almost in contact, but are sometimes separated by spaces equal to the diameter, rarely round. On the smaller branchlets they are placed on all sides, close together, usually leaving no bare median line. On the stalk and principal branches the bare median area is irregular and narrow, and in the dry specimens shows a narrow median groove, due to the main longitudinal peraxial duct.

The axis in the stalk and larger branches is very dark brown or nearly black, hard, slightly translucent; in the smaller branchlets it becomes nearly amber-color, translucent, and brittle. It is slightly calcareous and effervesces feebly with acids.

The cœnenchyma is firm, close-grained, composed of very small purple and yellow spicules.

The spicules are very small and vary but little in diameter. The greater number are reddish purple, rather slender, strongly warted double-spindles and spindles; most of them are rather acute, but some are obtuse. With these are some much shorter purple double-cones, double-rosettes, and rosette-cones, and a few more slender spindles with fewer warts. The scaphoid spicules are mostly bright yellow, usually strongly curved on the convex side, much less so on the concave side. The convex side often has a median emargination, or is girdled, and is usually smooth; there is frequently a row of lateral warts. The concave side has four to six strong warts or tubercles in each linear row; some of them are often bifid or lobulate. In some cases there is a naked middle zone, so as to produce a girdled or double scaphoid form.

With the yellow scaphoids there are also some regular, strongly warted, acute, yellow spindles, among them the largest of the spicules, and also some shorter, blunt, closely warted spindles and double-spindles equal in length to the scaphoids. Some very small short forms also occur.

The larger double-spindles measure 0.12×0.04; 0.09×0.03; 0.08×0.03; the stouter ones, 0.07×0.03; 0.06×0.03; slender ones, 0.06×0.02; 0.06×0.01; double-cones, 0.05×0.04; 0.05×0.03; double-rosettes, 0.08×0.03; 0.05×0.03; double-heads, 0.03×0.03; 0.03×0.02; scaphoids, 0.07×0.03; 0.06×0.03 mm.

The axis is brownish black, hard, and lustrous in the larger branches, becoming brownish yellow in the smaller ones, and translucent pale yellow in the terminal branchlets. It is more or less calcareous. The base is dull yellow, vermiculated at the surface, hard and calcareous, effervescing freely in acids.

The two types and only specimens seen are from Marannao, Brazil, collected by Derby and Wilmot and received from Mr. Richard Rathbun. Exped. C. F. Hartt, 1876, Nos. 4553 and 4554, Yale Museum.

Gorgonia braziliensis Verrill, sp. nov.

Plate XXIX, figures 3, 3a (branchlet and spicules of No. 4508, in natural colors). Plate XXXIII, figure 7 (spicules of the same). Plate XXXV, figures 7, 7a (calicles of the same).

Coral subdichotomously branched from close to the base, with few, long, slender, strongly divergent, terete branches, bright orange-yellow in the types. Total height of type (No. 4508), 260 mm.; breadth as dried, 240 mm.; length of longer branchlets, 150 to 190 mm.; diameter, about 2.5 mm. This specimen has only nine branchlets.

The calicles are small, scarcely raised, with the aperture small, oblong, or narrow elliptical. They form two alternating rows on each edge of the branchlets, leaving a narrow, naked median band, which is slightly grooved on the larger branches. The cœnenchyma is hard and nearly smooth.

The larger spicules are small, rather slender, acute, strongly warted, orange-colored double-spindles, with three or four whorls of graded warts on each end. With these are some shorter, blunt double-spindles, with but two whorls of warts on each half; a few roughly warted short spindles; and some double-rosettes, with a single whorl and a terminal cluster of warts. The scaphoids are smaller than the longer spindles, with the convex side not very much curved, and sometimes incurved in the middle; some have a few low humps on the back. The concave side usually has three pairs of rather large irregular warts. All are orange-colored.

The longer, slender double-spindles measure 0.12 × 0.03; 0.10 × 0.03; 0.09 × 0.02; 0.09 × 0.03; the stouter ones, 0.09 × 0.04; 0.07 × 0.03; 0.06 × 0.03; double-rosettes, 0.06 × 0.03; scaphoids, 0.07 × 0.03; 0.06 × 0.03; 0.06 × 0.02; tentacle-spindles, 0.06 × 0.01 mm.

The specimen described above (No. 4508) and figured is lighter orange than No. 4507, which is rather orange-red. Otherwise they agree well.

The axis is hard and brittle, it is impregnated with fusiform strands and scales of calcium carbonate. It effervesces with acids. In Javelle water it becomes white and shows calcareous deposits, which readily fall apart.

Mapelle, Bahia. Coll. Richard Rathbun., C. F. Hartt Exped., 1876. Types, Nos. 4507, 4508, Yale Museum.

Gorgonia gracilis Verrill.

Pterogorgia gracilis Verrill, Trans. Conn. Acad. Sci., vol. I, p. 358, pl. IV, figs. 2, 2a, 3, 1868.
Gorgonia gracilis Verrill, Amer. Journ. Sci., vol. XLVIII, p. 424, 1869. Hartt, op. cit., 1870, pp. 209, 210.

Plate XXIX, figure 2 (branch of type in natural colors). Plate XXXV, figure 5 (branch and calicles of same, purple var.); figure 5a (the same, yellow var.).

This slender branched species was fully described in 1868. It is notable for its variability in color. The most common color seems to be light purple with yellow calicles, but bright lemon-yellow specimens occur, as well as some amethyst-colored ones, and others that are mixed yellow and purple. The colors are due to the unequal mixtures of colored spicules; purple, yellow, and white. The axis contains some calcium carbonate and effervesces feebly with acids.

Common on the Abrolhos Reefs, below low-tide, and sometimes in tide-pools. Coll. C. F. Hartt, 1867.

PHYLLOGORGIA M.-Edw. and Haime, emended.

Phyllogorgia M.-Edw. and Haime, British Fossil Corals, Introd., p. lxxx, 1850.
Phyllogorgia + Hymenogorgia M.-Edw., Corall., vol. I, pp. 180, 181, 1857.

Gorgonidæ having the intervals between the branchlets and smaller branches filled in, more or less, by flat expansions of the cœnenchyma containing calicles, in the form of pores, and rows of nutrient canals beneath the surface. Axis flabelliform, branchlets free or anastomosing.

Substance of the axis may be horny or more or less calcareous. Spicules as in typical *Gorgonia;* scaphoids are present, with double-spindles.

In a former paper (1869) the writer proposed to reduce *Phyllogorgia* and *Hymenogorgia*, as well as *Xiphigorgia*, etc., to mere sections of the modernized genus *Gorgonia*, because the spiculation is characteristic and essentially identical in all these groups, while the mode of growth is various and of secondary importance.

The discovery of a variety (*lacerata*) of *P. quercifolia*, described below, in which some of the branchlets of a single specimen remain nearly terete, as in typical *Gorgonia;* while others are flattened, as in section *Pterogorgia;* others slightly winged, as in section *Xiphigorgia;* with many that are broadly winged or foliated, as in *Hymenogorgia*, confirms that view. (See Plate XXX, fig. 4 and Pl. XXXII, fig. 2.)

However, out of deference to the views of other writers, I have here retained *Phyllogorgia*, but so emended as to include *Hymenogorgia*, for our specimens show no essential distinctions, even in the matter of branching of the axis. The only distinction made by Edwards and Haime was that the branchlets anastomose in *Phyllogorgia* and do not in *Hymenogorgia*. I find anastomoses, also, in the typical variety of the latter.

Phyllogorgia quercifolia (Dana) Verrill.

Gorgonia quercus-folium Ehr., Corall., p. 143, 1834.
Pterogorgia quercifolia Dana, U. S. Expl. Exped., Zoöph., p. 647, 1846.
Hymenogorgia quercifolia Val., op. cit., p. 13. M.-Edw., Corall., vol. I, p. 181, 1867. Hartt, op. cit., pp. 62, 196, 210, 1870.
Gorgonia quercifolia Verrill, Trans. Conn. Acad. Sci., I, p. 359, pl. IV, figs. 1–1b, 1868.

Plate XXX, figure 3 (general figure of No. 1514, reduced). Plate XXXII, figure 1 (one of the "leaves" enlarged). Plate XXXIII, figures 1, 1a (spicules of the same).

Variety quercifolia.

The most typical specimen of this variety is 245 mm. high by 272 mm. broad. It is flabelliform and nearly all the main branches are partially separate and terminate in flat, deeply lobed, leaf-like expansions, closely resembling the strongly lobed leaves of certain oaks, but many are irregular.

The axis itself can be seen in outline, and especially when wet, by translucency, against a strong light. The stem divides subpinnately into a number of divergent primary branches and these send off numerous slender, divergent, alternating branchlets, many of which fork, each ultimate division ending in a lobe of the leaflets. In some places the small twigs anastomose, forming irregular, often rather large meshes, filled in completely by the cœnenchyma. Thus the distinction between *Hymenogorgia* and *Phyllogorgia*, based on anastomoses of the axis in the latter, does not hold good.

The spicules are yellow and purple, rather larger than in the related forms. The larger are roughly warted, acute double-spindles, with about four graded whorls of warts on each end. With these are stouter, similarly warted double-spindles, grading into closely warted double-cones.

The scaphoids are often girdled or indented on the convex side, with two or three low humps on each half. Each edge may have a row of three or four warts. The concave side has about four pairs of large warts.

The color of our specimens, when dry, is a delicate dull yellow, similar to pale ocher-yellow. The main stem and base are usually partly purple; sometimes the branches are tinged by purple spicules.

Periperí, Bahia, Brazil. Coll. Richard Rathbun, 1876. No. 4506, Yale Museum. Abrolhos Reefs, C. F. Hartt, 1867. According to Professor Hartt, this form is very common from Cape Frio to Pernambuco. Particularly abundant at the Abrolhos, Guarapary, Port Seguro, Bahia, and Victoria Bay. It ranges from low-tide to 6 feet depth or more, and also at times occurs in tide-pools. In life it is yellow or pink.

Phyllogorgia quercifolia, variety **lacerata** Verrill.

Plate XXX, figure 4 (general figure, reduced). Plate XXXII, figure 2 (branches of the same). Plate XXXIII, figure 2 (spicules of the same).

The type of this variety has the fronds reduced to a sort of skeleton, the divisions between the lobes becoming so large and deep that they reach nearly to the axis of the branches, leaving only a rather narrow foliated strip of the cœnenchyma on each side. In some parts this is further reduced, so that some of the smaller branches are nearly terete, or no more flattened than in the section *Pterogorgia* of *Gorgonia*, thus showing the close affinity between *Phyllogorgia* and typical *Gorgonia*.

The spicules are white, but essentially the same in form as in the variety *quercifolia*, though rather smaller.

The slender double-spindles measure 0.20 × 0.06; 0.18 × 0.05; 0.16 × 0.06; 0.17 × 0.05; 0.15 × 0.05; stouter double-spindles, 0.16 × 0.06; 0.13 × 0.06; scaphoids, 0.11 × 0.06; 0.11 × 0.05; crosses, 0.16 × 0.16 mm.

Total height, 220 mm.; breadth, 200 mm. The color of the type, as dried, was nearly white.

Periperí, Bahia, Brazil. Coll. Richard Rathbun. Type, No. 4505.

Phyllogorgia frondosa Verrill, sp. nov.

Plate XXXI, figure 2 (general figure of No. 1514, reduced). Plate XXXIII, figure 4 (spicules of the same). Plate XXXV, figure 8 (calicles of the same).

The coral of the type (No. 1514) is thin, flabelliform, spreading in one plane, divided by six deep, radial incisions into seven unequal, frond-like lobes, mostly with the distal end wider and undulated, or somewhat lobed, but with the lateral edges nearly entire, so that there is no resemblance to an oak-leaf, but rather to the fronds of certain algæ. The axis of the main branches, as seen by strong trasnmitted light, when wet, gives off numerous slender branches, which radiate toward the margin and become subparallel, with intervals of about 3 to 6 mm., while slender transverse branches connect them together and often form tri-

angular, squarish, or irregular angular meshes, often not more than 5 to 6 mm., square. These do not occur regularly in all parts and are probably inconstant, but it is the character given as distinctive of *Phyllogorgia*. The subparallel branchlets are no doubt more important than the anastomoses.

The cœnenchyma has a thin, smooth, compact, superficial layer of spicules; beneath this it is more porous with looser spicules. Between the two layers, in a transverse section, there is a row of numerous, small, nutrient canals, parallel with the surface, similar to those in the circle around the axis.

The calicle pores in this form seem to be larger than in *P. quercifolia*. They appear as unequal round pores, over the whole surface, except over the central lines of the axis.

The calicles on opposite sides of the fronds generally alternate and the bases of the polyp-cavities reach about half way through the thickness of the cœnenchyma. In some cases, however, they are opposite as seen in sections and in that case their bases are separated only by a thin septum.

The axis is dull black in the stem, becoming dull yellow and amber-yellow, in the branches. In the finer divisions it is very slender, translucent, and somewhat calcareous.

The color as dried (perhaps stained) is brownish orange with a tinge of purple, especially on the edges, due to many purple spicules among the pale yellow ones; on the base the color is bright purple; there is a layer of purple spicules around the axis. The prepared spicules are mixed amethyst-purple, rose-color, light yellow, and whitish. The greater number are stout, thick, blunt, closely warted double-spindles, with a narrow median girdle. They are shorter, much thicker, and more evenly and closely warted than in either of the allied species. Many, especially among the purple ones, are short, stout, double-cones and double-rosettes. There are also many more slender, subacute, double-spindles of both colors. The scaphoids are mostly white and much smaller than the spindles. They have the convex side smooth or nearly so and strongly curved. The small external spicules are double-heads, rosettes, double-rosettes, etc., both purple and pale yellow.

The more slender double-spindles measure 0.19 × 0.06; 0.19 × 0.05; 0.17 × 0.06; the stouter double-spindles, 0.15 × 0.07; 0.14 × 0.07; double-rosettes, 0.10 × 0.05; scaphoids, 0.15 × 0.05; 0.12 × 0.04; 0.11 × 0.05; 0.10 × 0.05; clubs, 0.04 × 0.05; crosses, 0.19 × 0.10; 0.14 × 0.14 mm.

Height, 170 mm.; breadth, 185 mm.

Abrolhos Reefs, Brazil. Coll. Prof. C. F. Hartt, 1867. Type, No. 1514, Yale Museum.

Phyllogorgia dilatata (Esper) M.-Edw. and Haime.

Gorgonia dilatata Esper, Pflanz., II, Fortsetz., p. 25, pl. 51, figs. 1, 2, 1790.
Phyllogorgia dilatata Edw. and Haime, Brit. Fossil Corals, Introd., p. 58, 1850. Val., op. cit., p. 130. M.-Edw., Corall., I, p. 181, 1857.
Gorgonia dilatata Verrill, Amer. Journ. Sci., vol. XLVIII, p. 425.

Plate XXXIII, figure 3 (spicules of the type of Edwards and Haime in the Paris Museum).

The larger spicules from the type of Edwards and Haime (slide No. 18, Köll.) are mostly rather slender, elongate, acute, strongly warted double-spindles, with the high warts rather openly placed in about three whorls on each half. With these are some equally large double-spindles with smaller and closer warts and many irregular forms, with a few small crosses. There are also smaller and shorter spindles with elevated warts. The scaphoids are often nearly as large as the spindles. The convex side is strongly convex, often with a few small humps; the concave side has about three irregular pairs of prominent warts.

The larger double-spindles measure 0.14 × 0.05; 0.13 × 0.06; 0.12 × 0.05; slender double-spindles, 0.13 × 0.04; 0.13 × 0.03; stouter ones, 0.14 × 0.04; 0.12 × 0.06; 0.12 × 0.05; 0.10 × 0.05; 0.09 × 0.05; 0.10 × 0.06; scaphoids, 0.11 × 0.05; 0.10 × 0.04; 0.09 × 0.05; 0.09 × 0.04; 0.09 × 0.03; crosses, 0.09 × 0.07.

Bahia, Brazil, M.-Edwards.

Phyllogorgia foliata (Val. Mss.).

Valenciennes, op. cit., t, XLI, p. 15 (no description). M.-Edw., Corall., I, p. 181 (no description).

Plate XXXIII, figure 5 (spicules of the type).

So far as known to me, no figures nor descriptions of this nominal species have been published.

It is said to have been from Guadeloupe, but no modern collector, so far as I know, has found it in the Antilles. As it is closely related to the two preceding species, and perhaps identical with *P. dilatata*, it is quite probable that it also came from Brazil.

The spicules from the type in the Paris Museum (slide 40, Köll.), are very much like those of *P. dilatata*. The most numerous are rather slender double-spindles with about three whorls of very prominent loosely placed warts on each end; with these there are some stouter spindles, more closely warted. The scaphoids are mostly smaller, very convex, mostly with a few small humps on the convex side; and often with a row of two or three lateral ones; the concave side has two or three pairs of very prominent warts.

The double-spindles and spindles measure 0.15 × 0.06; 0.13 × 0.07; 0.12 × 0.04; 0.11 × 0.05; 0.11 × 0.04; 0.10 × 0.05; scaphoids, 0.11 × 0.05; 0.10 × 0.04; 0.09 × 0.03 mm.

Guadeloupe, M.-Edwards. Locality doubtful.

Leptogorgia rathbunii Verrill, sp. nov.

Plate XXIX, figures 4, 4a (branch and spicules of No. 4555, in natural colors). Plate XXXV, figures 9, 9a (calicles of No. 4556. Plate XXXIII, figure 11 (spicules of the same).

This is a very elegant scarlet-red or coral-red species, branching freely pinnately in one plane, but not anastomosing. The larger specimen is 150 mm. high.

The branches are slender, irregularly pinnate and bipinnate, not varying much in thickness. All are slender; the terminal branchlets are mostly 10 to 20

mm. long, and 1 to 1.5 mm. in diameter; the larger branches are 2 mm. to 4 mm. thick. The branchlets and branches are strongly divergent, arising usually at angles of 60 to 90 degrees, rather straight, or curving upward only slightly.

The calicles are prominent, small, rounded verrucæ, often nearly as high as broad, mostly entirely closed at the apex, but often showing the aperture as a small, narrow slit. Diameter of calicles, 0.3 to 0.5 mm.; height, about 0.02 to 0.03 mm. They are placed closely together in two alternate rows on each edge of the branchlets, leaving only a narrow naked zone, which becomes wider on the branches and usually has a median groove. The bases of the calicles are usually in contact or nearly so.

The cœnenchyma is thin, hard, and smooth, scarlet-red. The axis is very slender, light yellow, translucent and brittle in the branchlets; darker yellow and hard, and slightly calcareous in the larger branches. It effervesces feebly in acids.

The prepared spicules are bright light-red, rather varied in form. The most abundant are rather stout, subacute double-spindles with about three close whorls of rough graded warts on each end, and a small terminal one; others are equally long but more slender and acute, with the three whorls of warts more separated. The short spicules are very small, red, spheroidal and ellipsoidal warted heads, with some short double-heads and minute double-rosettes. The tentacle-spicules are bright red, slender, irregular, often feebly microspinulose, acute spindles.

The larger double-spindles measure 0.09 × 0.04; 0.08 × 0.04; more slender ones, 0.07 × 0.03; 0.05 × 0.01; stouter ones, 0.06 × 0.03; 0.04 × 0.02; double-rosettes, 0.05 × 0.03; double-heads, 0.05 × 0.04; tentacle-spindles, 0.10 × 0.03; 0.04 × 0.01.

The spicules somewhat resemble those of *L. rosea* (from the type of Lamarck), but the latter are paler in color, more slender, more acute, and the short spicules are much larger and more ellipsoidal.

The larger specimen (No. 4555) is 150 mm. high and 165 mm. broad; diameter of stem and larger branches, 4 mm.; of branchlets, 1.25 to 2 mm.; length of terminal branchlets, mostly 10 to 15 mm. The smaller specimen is 75 mm. high by 65 mm. broad.

Parannao, Brazil, collected by Derby and Wilmot, Mr. Richard Rathbun. Hartt Expedition to Brazil. Types, Nos. 4555 and 4556, Yale Museum.

Leptogorgia rubropurpurea Verrill, sp. nov.

Plate XXIX, figures 5, 5a (branch and spicules of No. 4523, in natural colors). Plate XXX, figure 1 (branch of No. 4823). Plate XXXV, figures 10, 10a (calicles of 4823). Plate XXXIII, figure 8 (spicules of No. 4823).

The best specimen studied is deep purple, erect, shrub-like, about 160 m. high, with rather few subdichotomous branches, which arise at acute angles and ascend quickly, without anastomoses. The branches and branchlets do not vary

much in diameter and the main stem is no larger. The branchlets and branches are somewhat quadrangular, owing to the calicles being arranged mostly in four close rows. They are usually from 2.5 to 3 mm. in diameter. The naked band on the sides is narrow and rather indefinite and seldom shows more than a trace of a median furrow. The terminal branchlets are mostly 15 to 25 mm. long, sometimes 40 mm.

The calicles are rather large for the genus, rounded or dome-like, mostly completely closed, closely arranged, mostly in two rows on each edge of the branchlets, and usually nearly or quite in contact at their swollen bases. Their apertures, when visible, usually appear as very narrow oblong slits. The calicles are mostly about 1 to 1.2 mm. in diameter and 0.6 to 0.8 mm. high. The axis is hard, brittle when dry, brownish yellow and translucent in the stem; pale amber-color, slender and brittle in the branchlets.

The cœnenchyma is deep reddish-purple, nearly smooth, hard and compact, filled with minute, bright purplish-red spicules. The spicules are mostly in the form of short strongly warted or tubercled spindles and double-spindles, some acute and some obtuse, and with many small, much shorter and sometimes equally thick, darker colored double-rosettes and double-heads and heads. There are also many much more slender, acute, red tentacle-spindles with few small microspinules. Some small red crosses and other minute forms from the tentacles also occur. No scaphoid forms were found.

The larger double-spindles of No. 4523 measure 0.07 × 0.04; 0.08 × 0.03; 0.07 × 0.03; 0.06 × 0.03; the stouter ones, 0.06 × 0.04; more slender ones, 0.07 × 0.02; double-rosettes, 0.04 × 0.04; 0.04 × 0.04; 0.04 × 0.03; double-clubs, 0.05 × 0.03; ellipsoidal ones, 0.04 × 0.03; rosettes endwise, 0.04 × 0.04; 0.03 × 0.03; 0.02 × 0.02; tentacle-spindles, 0.08 × 0.02; 0.08 × 0.03; 0.05 × 0.02 mm.

The specimen described above was collected at Rio de Janeiro. Expedition of C. F. Hartt. No. 4523, Yale Museum.

Leptogorgia pumicea (Val.) Verrill.

Gorgonia pumicea Val., Compt.-rend., XLI, p. 12. M.-Edw., Corall., vol. I, p. 160, 1857.
Leptogorgia pumicea Verrill, Amer. Journ. Sci., XLVIII, p. 422, 1869.

Plate XXXIII, figure 10 (spicules of type); figure 9 (spicules of No. 892). Plate XXXV, figure 11 (branchlet of No. 892).

The spicules from the type in the Paris Museum (slide 27, Köll.) are very small, bright red double-spindles and relatively large garnet-red spheroids. The double-spindles are partly rather short, thick, blunt, with two close whorls of rough warts on each end, and partly rather longer, slender, acute double-spindles, with three whorls of small graded warts on each end; many of intermediate forms occur.

The short spicules are often as thick as the larger spindles, and are conspicuous on account of their dark red color. They are partly warted spheroidal heads,

with some ellipsoids with a single median whorl of warts; short, close double-heads and double-cones. The tentacle-spicules are bright red, slender, acute, nearly smooth spindles, often as long as the warted spindles.

The more slender double-spindles of the type measure 0.14 × 0.04; 0.13 × 0.03; 0.12 × 0.04; 0.12 × 0.03; stouter double-spindles, 0.11 × 0.04; 0.10 × 0.06; 0.10 × 0.05; 0.09 × 0.05; double-rosettes, 0.08 × 0.05; rosettes, 0.06 × 0.05; 0.06 × 0.06; 0.06 × 0.04; 0.05 × 0.04; tentacle spicules, 0.11 × 0.02; 0.10 × 0.03 mm.

The slide was labelled by Professor Kölliker as from the type in the Paris Museum, collected by M. Dupres, 1842. Milne-Edwards gives Brazil as its origin. A branch from a large specimen (No. 892) collected by Prof. James D. Dana, on the Wilkes U. S. Exploring Expedition, in the Bay of Rio de Janeiro, was referred to this species by me in 1869. It was received from the Smithsonian Institution about 1861.

The original description is so brief that the identification would be quite conjectural without the spicules of the original type, which were sent to me by Professor Kölliker. It is nearly allied to the preceding species, with which it agrees pretty nearly in color and in the four-rowed arrangement of the calicles. The color, however, is paler and more nearly wine-red, while the calicles are not alf as large and much less prominent. The mode of branching is more distinctlyh pinnate and the branches are more numerous, shorter, and much more slender, being less than half as thick.

Total length of branch, 95 mm.; length of terminal branchlets, 10 to 15 mm.; their diameter, 1 to 1.2 mm.; diameter of calicles, 0.5 mm. and less.

The more slender larger double-spindles of No. 892 measure 0.12 × 0.05; 0.11 × 0.05; 0.10 × 0.04; stouter ones, 0.11 × 0.06; 0.10 × 0.05; double-heads, 0.06 × 0.03; rosettes endwise, 0.07 × 0.05; 0.06 × 0.05; 0.05 × 0.05; crosses, 0.08 × 0.06 mm.

The spicules are much like those of *L. rubropurpurea*, but are smaller. An examination of a large series of specimens might show that they are only local varieties of one species, though so unlike in size of calicles, etc.

Leptogorgia studeri Verrill, new name.

Leptogorgia purpurea Wright and Studer, Voy. Challenger, XXXI, p. 151, pl. XXIX, figs. 1, 1a; pl. XXXIV, fig. 3 (*non* Pallas, *nec* Verrill, 1864).

A new name is here proposed for the Brazilian specimens obtained by the "Challenger" and figured by Wright and Studer on their plates 29 and 34.

It is a light red species branching pinnately, somewhat as in *L. rathbuni*, with slender, short, rigid, nearly straight, divergent branchlets, unlike *L. pumicea* and *L. rubropurpurea*, with which the authors cited confounded it.

The spicules, moreover, are very unlike those of any other species known to me. The larger ones are remarkably short, stout, blunt, ellipsoidal double-spindles, very closely warted. Whether the specimen taken by the "Challenger"

in 400 fathoms, west of Chili, and referred to this species by the same authors, is identical seems to me extremely doubtful, for at that depth the water is very cold, while in the shallow water off Bahia it is tropical. Probably a careful study of the spicules would show valid distinctions.

Off Bahia, in 10 to 20 fathoms, Challenger Expedition. Type. The name *purpurea* has been applied to several other species of gorgonians, mostly belonging to *Leptogorgia*. The original *Gorgonia purpurea*, of Pallas, was a slender, virgate species apparently the common purple variety of the South Carolinian species usually called *L. virgulata* Lam. (purple variety); *L. viminea* Ellis and Sol. (yellow variety); and by other names. *L. purpurea* is the earliest.

The following is a free translation of the description of Pallas:

Gorgonia subdichotomous with the branches divaricate virgate; cœnenchyma violaceous, subverrucose. Axis terete, black, smooth; tips yellow, flagellate. Stalk unequally dichotomous; branches few, divaricate, ascending. Cœnenchyma thick, violaceous, rough (scaber); pores alternate, oblong, scattered, a little prominent. Base much expanded, fuscous gray, attached to an oyster. American Sea.

From the above it is evidently a purple *Leptogorgia*, with slender virgate branches, like *L. virgulata* of South Carolina, and not at all like the Brazilian species referred to it.

Family ELLISELLIDÆ Gray = **GORGONELLIDÆ** Verrill and others.

Gorgonellacees Val., 1855. M.-Edw., Corall., vol. I, p. 182, 1857.
Elliselladæ Gray, Proc. Zool. Soc. London, 1859, p. 480. Catal. Lithophytes, p. 24, 1870.
Gorgonellidæ Verrill, Proc. Essex Inst., Salem, Mass., vol. IV, pp. 148, 189, 1865.

Although it may be necessary hereafter to reduce this group to a subfamily of Gorgonidæ, as stated under the latter (p. 390), I do not wish to discuss the question here, for the group is scarcely known from Brazil. It is abundant in the "Blake" Alcyonaria from the Antilles.

Numerous species have been well figured and the genera will be revised in my forthcoming report on that collection.

At present it is separated from the Gorgonidæ only by the more calcareous axis,—a notably variable character in the Gorgonidæ, as well as in the Plexauridæ and some other families.

Besides this character, it may be added that in addition to the small, double-spindles, there are some short forms of double-heads, double-clubs, double-cones, etc., that are densely warted and often very characteristic.

Elliselladæ has priority over Gorgonellidæ as the family name. Since it seems necessary to adopt the genus *Ellisella* Gray (restricted), having *E. elongata* as the type, there is no longer any reason for discarding Gray's family name. The genus *Gorgonella* (type *G. sarmentosa*) is perhaps the least characteristic member of the family. Its calicles are quite immersed, its spicules nearly as in *Leptogorgia*, and its axis is often only feebly calcareous, much as in *L. rathbuni* and *Gorgonia braziliensis*, so that it is very close to *Leptogorgia*.

VIMINELLA Gray.

Viminella Gray, Catal. Lithophytes, p. 28, 1870. Type *V. flagellum* (J.)
Juncella (*pars*) M.-Edw., 1857.
Scirpearia of authors (not of Cuvier).
Scirpearella W. and Studer, op. cit., 1889, p. 154.

Corals unbranched or sparingly branched. Calicles usually prominent, often incurved distally in contraction. Axis round, highly calcareous.

Spicules are largely double-spindles, with many small double-cones and double-heads, finely warted.

I prefer to take Gray's second species as the type, because it was personally well known to him. The first species, *V. viminea* Edw., belongs to the same genus, as shown by spicules from the type in my collection.

The same is true, also, in respect to *V. lævis* (Verrill), China, which is Gray's fourth species. Numerous species, some of large size, occur in the Antilles, in deep water.

Viminella hystrix (Val.) Gray.

Juncella hystrix M.-Edw., Corall., vol. I, p. 186, 1857. (Description insufficient.)
Viminella hystrix Gray, Catal. Lith., p. 29, 1870.

This species has not been recognizably described nor figured. It is said to be a slender, unbranched species with very prominent calicles.

Its spicules were not among those of the Paris Museum types sent to me by Professor Kölliker. It doubtless belongs to Gray's genus *Viminella*.

Bahia, Brazil (M.-Edw.).

LIST OF SPECIES.

MURICEIDÆ.

Muricea humilis (Edw.) V.
Muricea humilis, var. mutans V.
Muricea humilis, var. macra V.
Muricea acropora V.
Muricea bicolor V.

PLEXAURIDÆ.

Plexaurella obesa V.
Plexaurella cylindrica V.
Plexaurella braziliana V.
Plexaurella pumila V.
Plexaurella verrucosa V.
Plexaurella grandiflora V.
Eunicea castelnaudi Edw.
Filigella gracilis Gray.

GORGONIDÆ.

Gorgonia hartti V.
Gorgonia braziliensis V.
Gorgonia gracilis V.
Phyllogorgia quercifolia (Ehr.).
Phyllogorgia quercifolia, var. lacerata V.
Phyllogorgia frondosa V.
Phyllogorgia dilatata E. and H.
Phyllogorgia foliata (Val. Mss.).
Leptogorgia rathbuni V.
Leptogorgia rubropurpurea V.
Leptogorgia pumicea (Val.).
Leptogorgia studeri V.

ELLISELLIDÆ.

Viminella hystrix (Edw.).

Deep Water Species Mentioned.

MURICEIDÆ.

Evacis bicolor V.

PRIMNOIDÆ.

Primnoëlla nitida V.
Primnoëlla distans W. and S.
Primnoëlla magellanica Studer.
Primnoëlla murrayi W. and S.
Stenella acanthina W. and S.
Stenella johnsoni W. and S.

Extralimital Species Mentioned or Discussed.

MURICEIDÆ.

Evacis rosea V.
Evacis solitaria (P.) V.

PLEXAURIDÆ.

Plexaurella anceps (D. and M.).
Plexaurella dichotoma (Esper) K.
Plexaura homomalla (Lam.) Lx.
Plexaura flavida (Lam.) Val.
Plexaura esperi V.
Plexaura olivacea Lx.
Pseudoplexaura crassa (Ellis and S.) W. and S.
Euniceopsis grandis V.
Astrogorgia sinensis V.
Heterogorgia verrucosa V.

GORGONIDÆ.

Leptogorgia virgulata (Lam.) Edw.
Leptogorgia viminea (Ellis and Sol.), Edw.
Leptogorgia purpurea (Pallas) Edw.
Leptogorgia rosea (Lam.) Edw.
Leptogorgia sanguinea (Lam.) Edw.

ELLISELLIDÆ.

Gorgonella sarmentosa (Lam.) Val.
Ellisella elongata (Esper) Gray.
Viminella lævis V.
Viminella viminea (Edw.) Gray.

BRIAREIDÆ.

Suberogorgia suberosa (Esper) Köll.

EXPLANATION OF PLATES.

PLATE XXIX.

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FIG. 1. *Muricea humilis* (Edw.) V. A terminal branch of No. 1515a, × 3 377
1a. The same, spicules, in natural colors; *a*, *b*, spinose clubs from the exterior; *d*, unilaterally spinose spindle; *c*, regular warted spindle from the interior; *e*, *f*, *g*, small purple spindles from the exterior, × 124 377
2. *Gorgonia gracilis* V. A branchlet from the type, in natural colors, × 3 393
3. *Gorgonia braziliensis* V. Part of a branchlet from the type, No. 4508, × 3 392
3a. The same. Spicules in natural colors; *a*, double-spindle; *b*, double-rosette; *c*, scaphoid, × 480 392
4. *Leptogorgia rathbuni* V. Branch from the type, No. 4555, × 3 397
4a. The same. Spicules; *a*, regular warted spindle; *b*, double-spindle; *c*, double-rosette; *d*, slender acute spindle from the tentacles, × 480 397
5. *Leptogorgia rubropurpurea* V. Branches of type, No. 4523, × 2 3/4 398
5a. The same. Spicules; *a*, double-rosettes; *b*, cross; *c*, short double-spindle or double-cone, × 480 398
6. *Gorgonia hartti* V. Terminal branches of type, No. 4554, × 2 3/4 391
6a. The same. Spicules; *a*, stout purple spindle; *b*, purple double-rosette; *c*, yellow elongated acute spindle from near the surface; *d*, yellow scaphoid from outer layer, × 480 391

PLATE XXX.

FIG. 1. *Leptogorgia rubropurpurea* V. Branches of the type, No. 4523, × 1 7/8 398
2. *Gorgonia hartti* V. Tip of the frond of the type, × 1 7/8, No. 4554 391
3. *Phyllogorgia quercifolia* (D.), var. *quercifolia*. General figure, 4/7 nat. size, of No. 4506. 394
3. The same. Var. *lacerata* V. General figure of the type, 4/7 nat. size, of No. 4505 395

PLATE XXXI.

FIG. 1. *Leptogorgia rathbuni* V. General figure, 3/4 size, of the type, No. 4555 397
2. *Phyllogorgia frondosa* V. General figure, 3/4 size, of the type, No. 1514b 395
3. *Plexaurella obesa* V. General figure, 3/5 size, of the type, No. 4509 383
4. *Plexaurella verrucosa* V. General figure, 3/5 size, of the type, No. 4503 387
5. *Plexaurella pumila* V. General figure of the type, 3/5 size, No. 4502 386
6. *Plexaurella grandiflora* V. General figure, 3/5 size, of the type, No. 4501 388

PLATE XXXII.

FIG. 1. *Phyllogorgia quercifolia* (Dana), var. *quercifolia*. One of the leaf-like fronds, × 1 3/4, No. 4506 394
2. The same. Var. *lacerata* V. Three branchlets from one specimen, × 1 3/4, No. 4505. 395
3. *Muricea acropora* V. Secondary branch from the type, × 1 3/5, No. 4510 379
4, 5. *Muricea humilis* (Edw.) Branches from two specimens of variety *pumila*, × 1 3/5, No. 1515a, b 377
6. *Plexaurella verrucosa* V. Part of a branch of the type, × 1 3/5, No. 4503 387
7. *Plexaurella cylindrica* V. Part of a branch of the type, × 1 3/5, No. 1597 384
8. *Plexaurella pumila* V. Part of a branch of the type, × 1 3/5, No. 4502 386
9. *Plexaurella obesa* V. Tip of a branchlet, × 1 3/5, from the type, No. 4509 383
10. *Plexaurella* (*Pseudeunicea*) *grandiflora* V. Tip of a small branchlet of the type, × 1 3/5, No. 4501 388

PLATE XXXIII.

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FIG. 1. *Phyllogorgia quercifolia* (Dana) V. Characteristic spicules from the normal form, × 146 394
2. The same. Characteristic spicules from var. *quercifolia*, No. 1514, × 190 394
2. The same. Var. *lacerata* V. Characteristic spicules, × 190, of No. 4505 395
3. *Phyllogorgia dilatata* Edw. Characteristic spicules from the type in the Paris Museum, × 190 396
4. *Phyllogorgia frondosa* V. Spicules of the type, No. 1514b, × 190 395
5. *Phyllogorgia foliata* (Val. Mss.). Spicules from the type in the Paris Museum, × 146 .. 397
6. *Gorgonia hartti* V. Purple spicules of the type, No. 4554, × 190 391
6a. The same specimen. Yellow spicules from near the surface, × 190 391
7. *Gorgonia braziliensis* V. Spicules of the type, No. 4508, × 190 392
8. *Leptogorgia rubropurpurea* V. Spicules from the type, No. 4523, × 190 398
9. *Leptogorgia pumicea* (Val.). Spicules from No. 892, × 190 399
10. *Leptogorgia pumicea* (Val.). Spicules from the type in the Paris Museum, × 190 399
11. *Leptogorgia rathbuni* V. Spicules of the type, No. 4556, × 190 397

PLATE XXXIV.

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FIG. 1. *Plexaurella* (*Pseudeunicea*) *grandiflora* V. Characteristic spicules of type, No. 4501, × 132 388
2. *Plexaurella pumila* V. Characteristic spicules of type, No. 4502, × 132; *g*, a peculiar large, bisymmetrical twinned spicule consisting of two united crosses; *b*, an unusual form, a large cone-club 386
3. *Plexaurella braziliana* V. Characteristic spicules of the type, No. 1598; *m*, an irregular twinned spicule or imperfect cross; *i*, *i'*, tripartite forms, × 132 385
3a. The same. Four of the more regular crosses, × 132 385
4. *Plexaurella cylindrica*, No. 1597. Characteristic spicules of the type; *h*, a peculiar large irregularly twinned spicule, × 132 384
5. *Plexaurella verrucosa* V. No. 4503. Characteristic spicules of the type; *d*, a peculiar doubly twinned form, × 132 387
6. *Plexaurella obesa* V. No. 4509. Characteristic spicules of the type; *f*, *f'*, large irregular and imperfect crosses, × 132 383

PLATE XXXV.

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FIG. 1, 1a. *Muricea acropora* V. Characteristic spicules; *a* to *e*, warted spindles from the interior; spindles with sharp spinules on one side, from the outer layers; *k*, *l*, the same but with spinules mostly near the end, approximating to clubs; *n*, *o*, spinose clubs; *m*, a large spindle with branched spinose outgrowths on one side. Type, × 120 379
2. *Muricea humilis* (Edw.) V. End of a branch of var. *humilis*, × 7 377
3, 3a. *Plexaurella grandiflora* V. Spindle-shaped bodies from the young axis, near tips, × 120 388
4. *Plexaurella cylindrica* V. Characteristic spicules; *a* to *c*, regular and subregular crosses; *d* to *i*, irregular or unequal rayed crosses or twinned forms; *h*, *h'*, triquetral forms; *k*, *l*, spindles; *n*, *n'*, small double-heads from the external layer. Type 384
5, 5a. *Gorgonia gracilis* V. (5*a* purple; 5*b*, yellow var.). Type, × 7 393
6. *Gorgonia hartti* V. One of the meshes to show calicles. Type, × 14 391
7, 7a. *Gorgonia braziliensis*, V. Side and profile views of a branch of the type, × 14 392
8. *Phyllogorgia frondosa* V. Portion of frond to show calicles of type, × 7 395
9, 9a. *Leptogorgia rathbuni* V. Portions of two branchlets of type, × 14 397
10, 10a. *L. rubropurpurea* V. Tip and middle of a branchlet of the type, × 14 398
11. *L. pumicea* (Val.). Portion of a branchlet of No. 892, × 14 399
12, 12a. *Plexaurella braziliana* V. Tangential section and portion of the exterior of the type, × 3.7 385
13, 13a. *Plexaurella verrucosa* V. Transverse and tangential sections of the type, × 3.7 387
14. *P. cylindrica* V. Tangential section of the type, × 3.7 384
15. *P. braziliana* V. Tangential section seen by transmitted light; *p*, *p'*, polyp-cavities; the small white spots are open ends of tubules, × 24 385

PLATE XXIX.

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FIG. 1. *Muricea humilis* (Edw.) V. A terminal branch of No. 1515a, × 3 377

1a. The same, spicules, in natural colors; *a*, *b*, spinose clubs from the exterior; *d*, unilaterally spinose spindle; *c*, regular warted spindle from the interior; *e*, *f*, *g*, small purple spindles from the exterior, × 124 377

2. *Gorgonia gracilis* V. A branchlet from the type, in natural colors, × 3 393

3. *Gorgonia braziliensis* V. Part of a branchlet from the type, No. 4508, × 3 392

3a. The same. Spicules in natural colors; *a*, double-spindle; *b*, double-rosette; *c*, scaphoid, × 480 392

4. *Leptogorgia rathbuni* V. Branch from the type, No. 4555, × 3 397

4a. The same. Spicules; *a*, regular warted spindle; *b*, double-spindle; *c*, double-rosette; *d*, slender acute spindle from the tentacles, × 480 397

5. *Leptogorgia rubropurpurea* V. Branches of type, No. 4523, × 2 3/4 398

5a. The same. Spicules; *a*, double-rosettes; *b*, cross; *c*, short double-spindle or double-cone, × 480 398

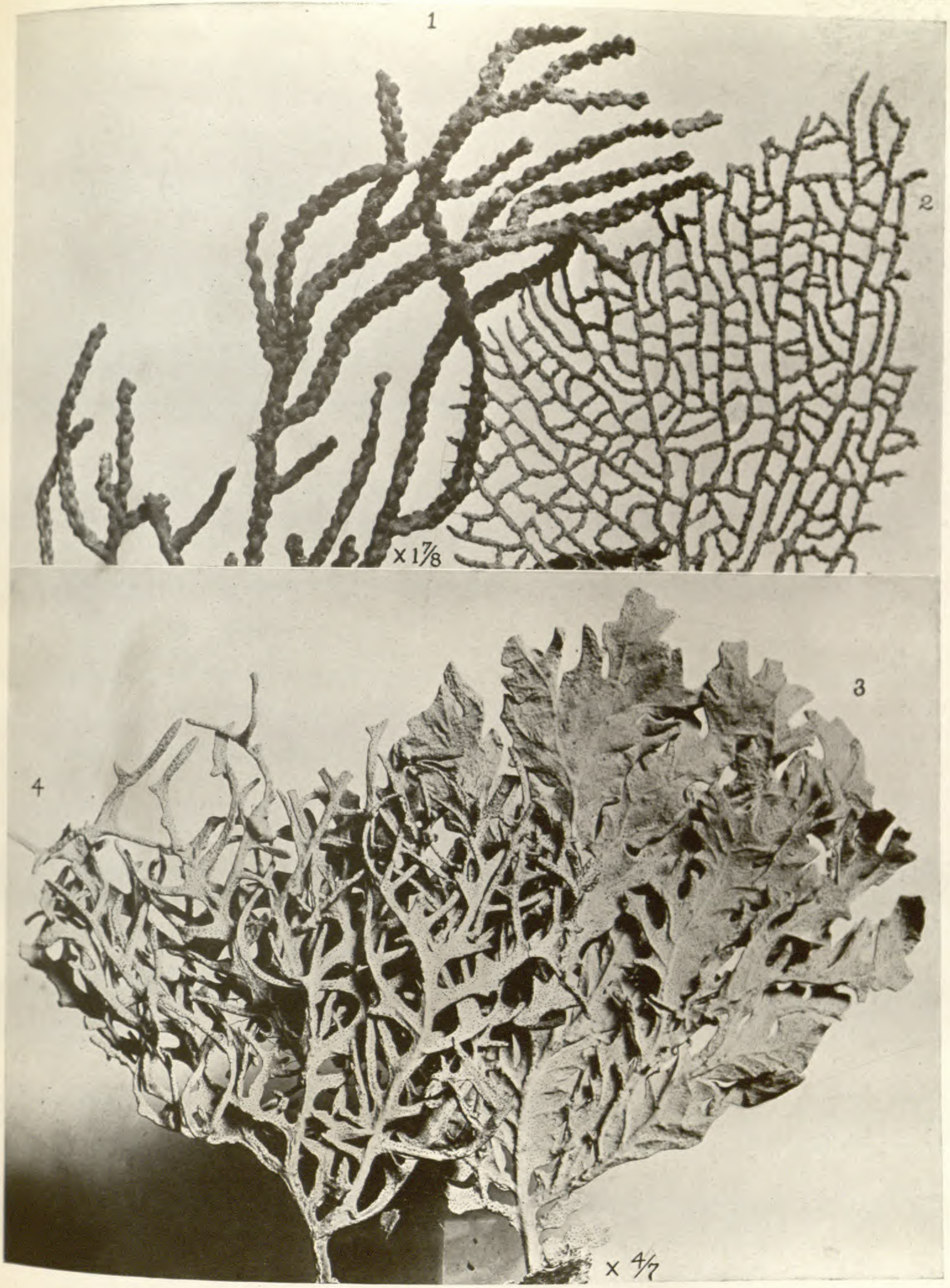
6. *Gorgonia hartti* V. Terminal branches of type, No. 4554, × 2 3/4 391

6a. The same. Spicules; *a*, stout purple spindle; *b*, purple double-rosette; *c*, yellow elongated acute spindle from near the surface; *d*, yellow scaphoid from outer layer, × 480 391

VERRILL: GORGONIANS OF BRAZILIAN COAST.

PLATE XXX.

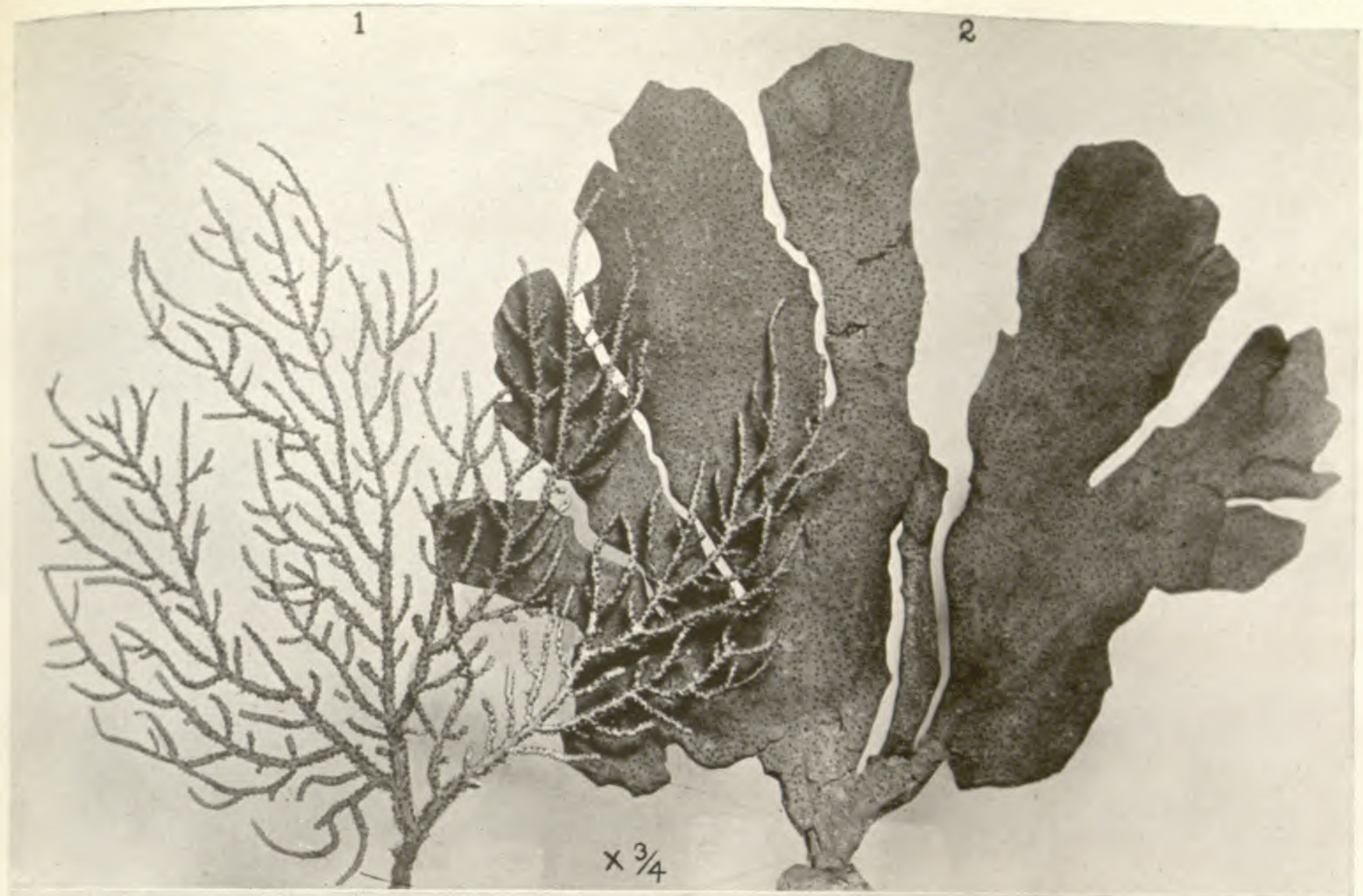
FIG. 1. *Leptogorgia rubropurpurea* V. Branches of the type, No. 4523, × 1 7/8..... 398
2. *Gorgonia hartti* V. Tip of the frond of the type, × 1 7/8, No. 4554..... 391
3. *Phyllogorgia quercifolia* (D.), var. *quercifolia*. General figure, 4/7 nat. size, of No. 4506. 394
3. The same. Var. *lacerata* V. General figure of the type, 4/7 nat. size, of No. 4505.... 395



VERRILL: GORGONIANS OF BRAZILIAN COAST.

PLATE XXXI.

FIG. 1. *Leptogorgia rathbuni* V. General figure, 3/4 size, of the type, No. 4555..... 397
2. *Phyllogorgia frondosa* V. General figure, 3/4 size, of the type, No. 1514b..... 395
3. *Plexaurella obesa* V. General figure, 3/5 size, of the type, No. 4509..... 383
4. *Plexaurella verrucosa* V. General figure, 3/5 size, of the type, No. 4503..... 387
5. *Plexaurella pumila* V. General figure of the type, 3/5 size, No. 4502..... 386
6. *Plexaurella grandiflora* V. General figure, 3/5 size, of the type, No. 4501..... 388



VERRILL: GORGONIANS OF BRAZILIAN COAST.

PLATE XXXII.

FIG. 1. *Phyllogorgia quercifolia* (Dana), var. *quercifolia*. One of the leaf-like fronds, × 1 3/4, No. 4506 394

2. The same. Var. *lacerata* V. Three branchlets from one specimen, × 1 3/4, No. 4505. 395

3. *Muricea acropora* V. Secondary branch from the type, × 1 3/5, No. 4510 379

4, 5. *Muricea humilis* (Edw.) Branches from two specimens of variety *pumila*, × 1 3/5, No. 1515a, b 377

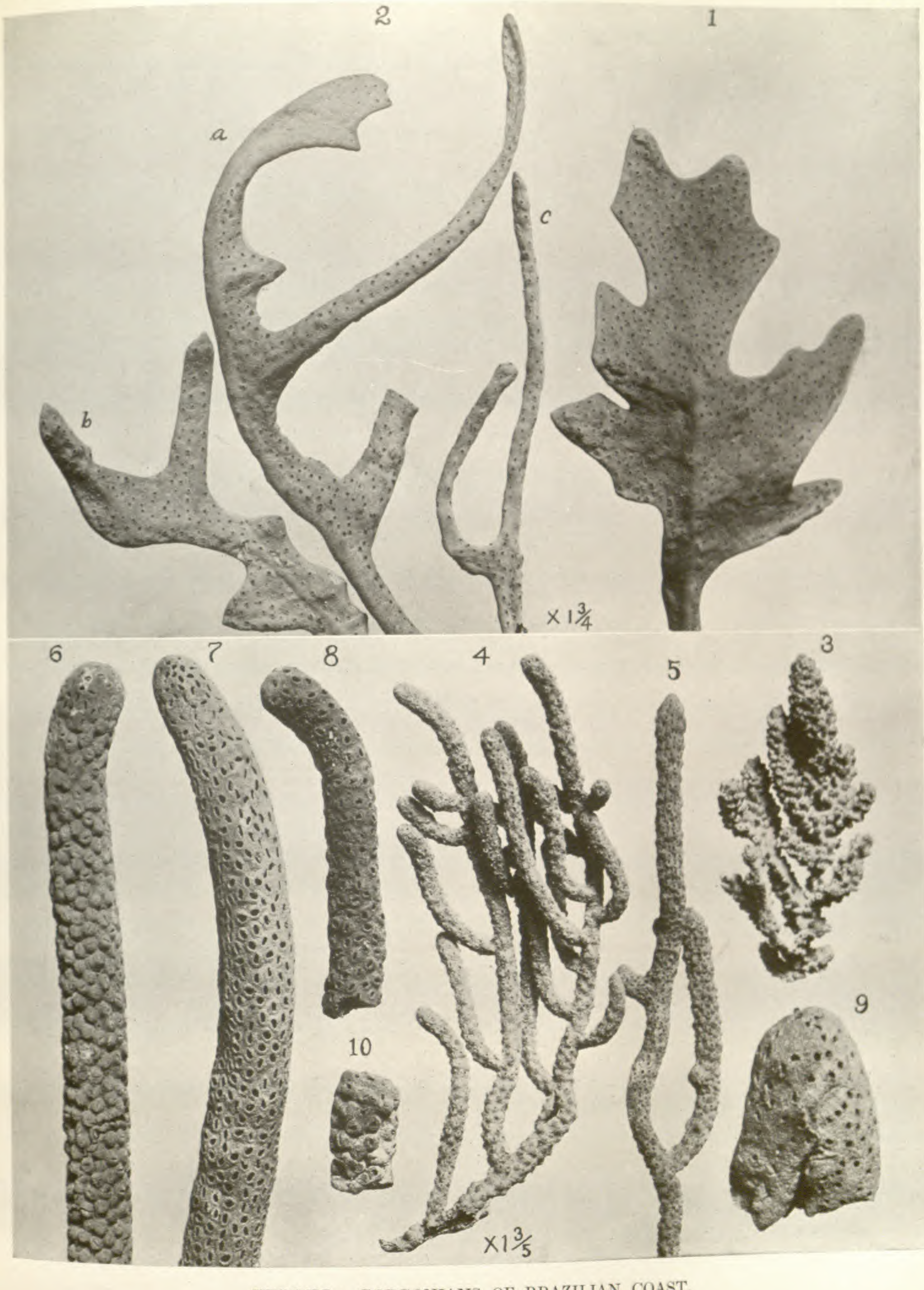
6. *Plexaurella verrucosa* V. Part of a branch of the type, × 1 3/5, No. 4503 387

7. *Plexaurella cylindrica* V. Part of a branch of the type, × 1 3/5, No. 1597 384

8. *Plexaurella pumila* V. Part of a branch of the type, × 1 3/5, No. 4502 386

9. *Plexaurella obesa* V. Tip of a branchlet, × 1 3/5, from the type, No. 4509 383

10. *Plexaurella* (*Pseudeunicea*) *grandiflora* V. Tip of a small branchlet of the type, × 1 3/5, No. 4501 388



VERRILL: GORGONIANS OF BRAZILIAN COAST.

PLATE XXXIII.

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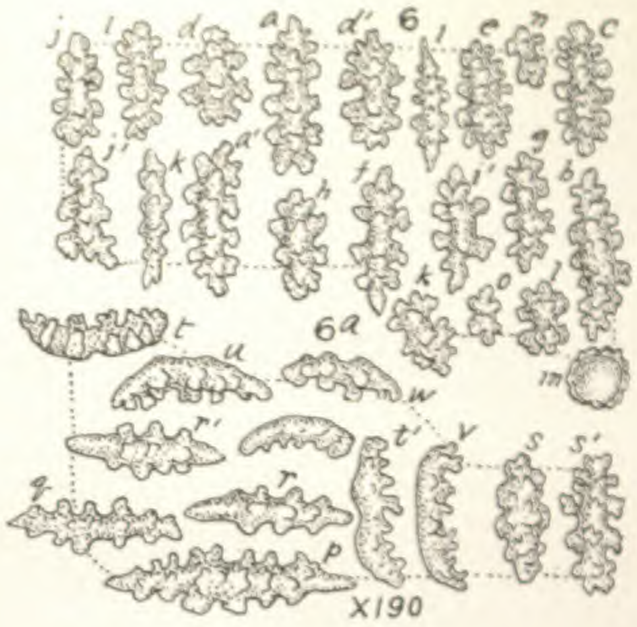
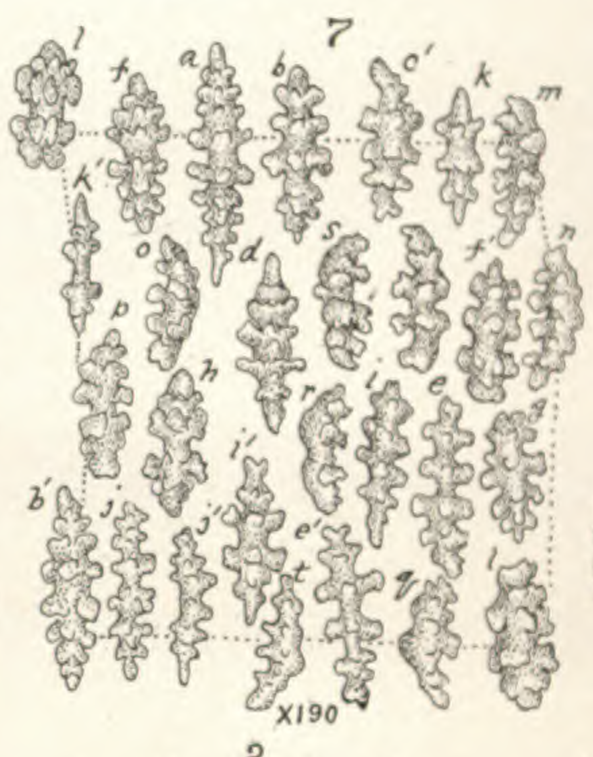
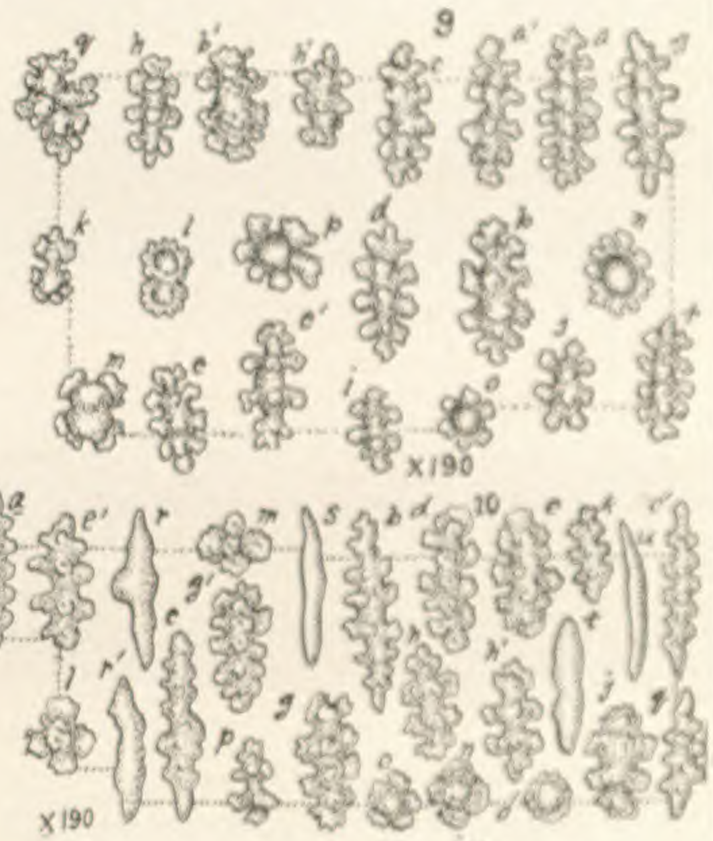
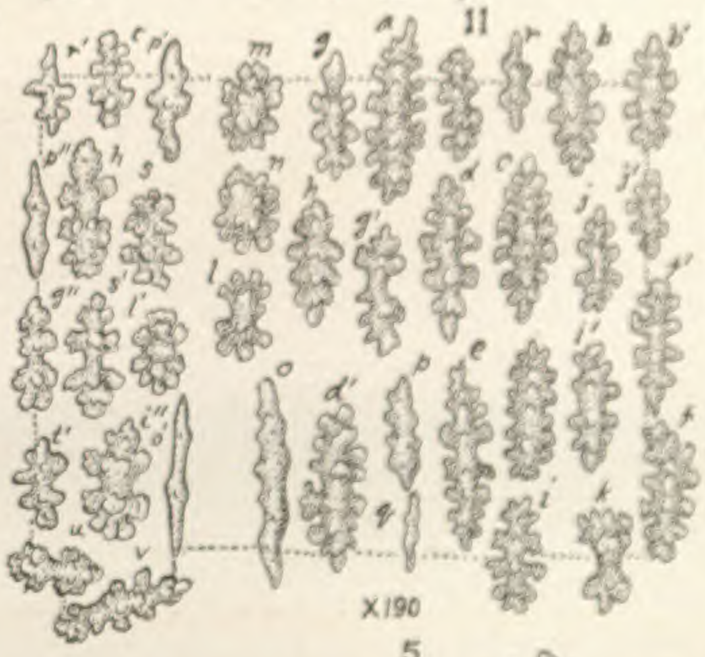
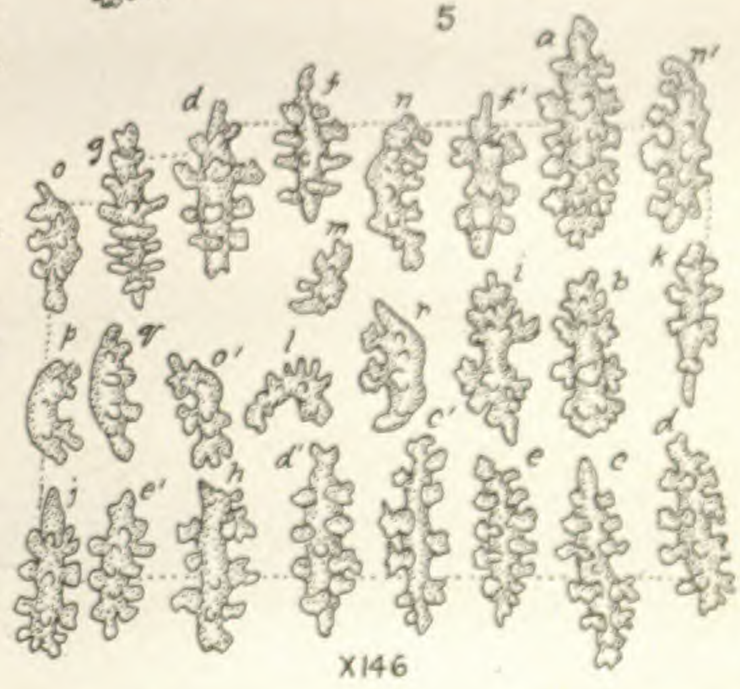
FIG. 1. *Phyllogorgia quercifolia* (Dana) V. Characteristic spicules from the normal form, × 146 394
2. The same. Characteristic spicules from var. *quercifolia*, No. 1514, × 190 394
2. The same. Var. *lacerata* V. Characteristic spicules, × 190, of No. 4505 395
3. *Phyllogorgia dilatata* Edw. Characteristic spicules from the type in the Paris Museum, × 190 396
4. *Phyllogorgia frondosa* V. Spicules of the type, No. 1514b, × 190 395
5. *Phyllogorgia foliata* (Val. Mss.). Spicules from the type in the Paris Museum, × 146 .. 397
6. *Gorgonia hartti* V. Purple spicules of the type, No. 4554, × 190 391
6a. The same specimen. Yellow spicules from near the surface, × 190 391
7. *Gorgonia braziliensis* V. Spicules of the type, No. 4508, × 190 392
8. *Leptogorgia rubropurpurea* V. Spicules from the type, No. 4523, × 190 398
9. *Leptogorgia pumicea* (Val.). Spicules from No. 892, × 190 399
10. *Leptogorgia pumicea* (Val.). Spicules from the type in the Paris Museum, × 190 399
11. *Leptogorgia rathbuni* V. Spicules of the type, No. 4556, × 190 397











VERRILL: GORGONIANS OF BRAZILIAN COAST.

PLATE XXXIV.

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FIG. 1. *Plexaurella* (*Pseudeunicea*) *grandiflora* V. Characteristic spicules of type, No. 4501, × 132 388

2. *Plexaurella pumila* V. Characteristic spicules of type, No. 4502, × 132; *g*, a peculiar large, bisymmetrical twinned spicule consisting of two united crosses; *b*, an unusual form, a large cone-club 386

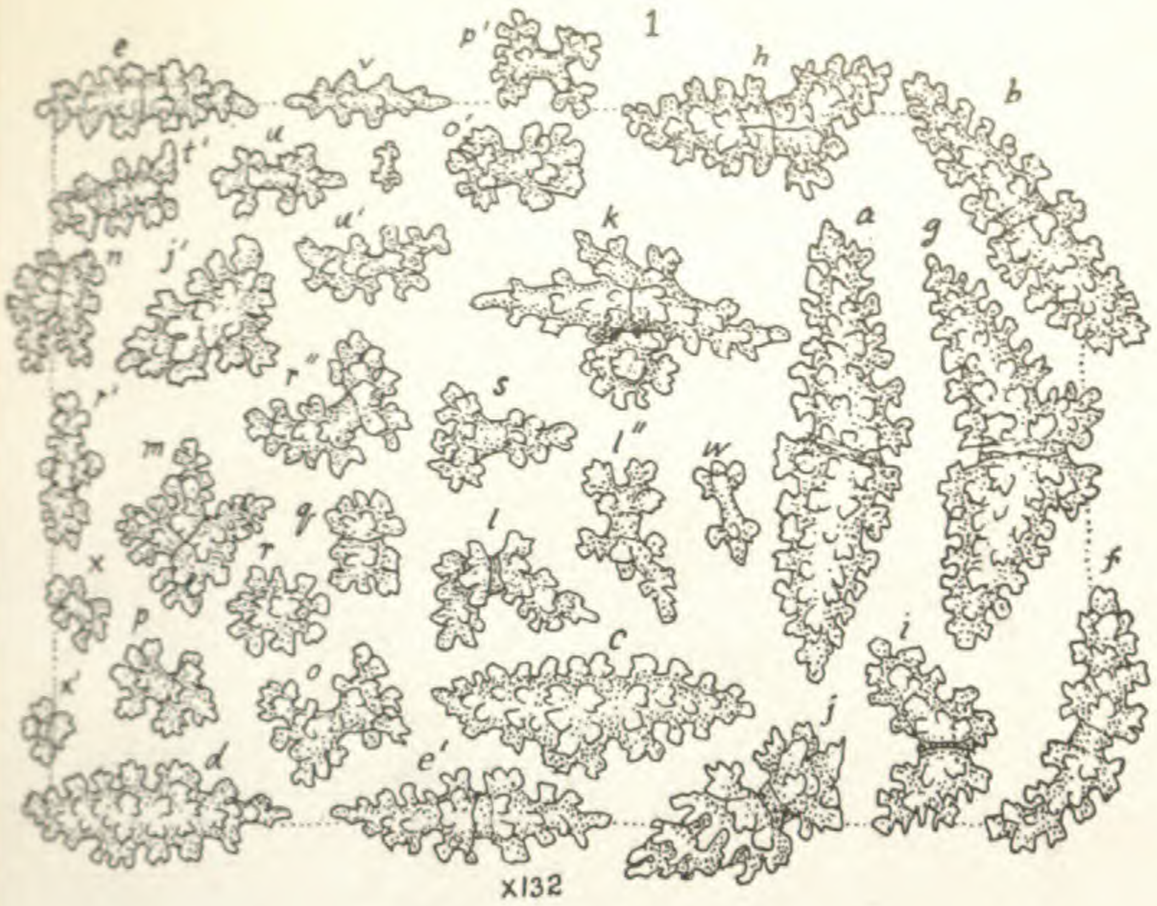
3. *Plexaurella braziliana* V. Characteristic spicules of the type, No. 1598; *m*, an irregular twinned spicule or imperfect cross; *i*, *i'*, tripartite forms, × 132 385

3a. The same. Four of the more regular crosses, × 132 385

4. *Plexaurella cylindrica*, No. 1597. Characteristic spicules of the type; *h*, a peculiar large irregularly twinned spicule, × 132 384

5. *Plexaurella verrucosa* V. No. 4503. Characteristic spicules of the type; *d*, a peculiar doubly twinned form, × 132 387

6. *Plexaurella obesa* V. No. 4509. Characteristic spicules of the type; *f*, *f'*, large irregular and imperfect crosses, × 132 383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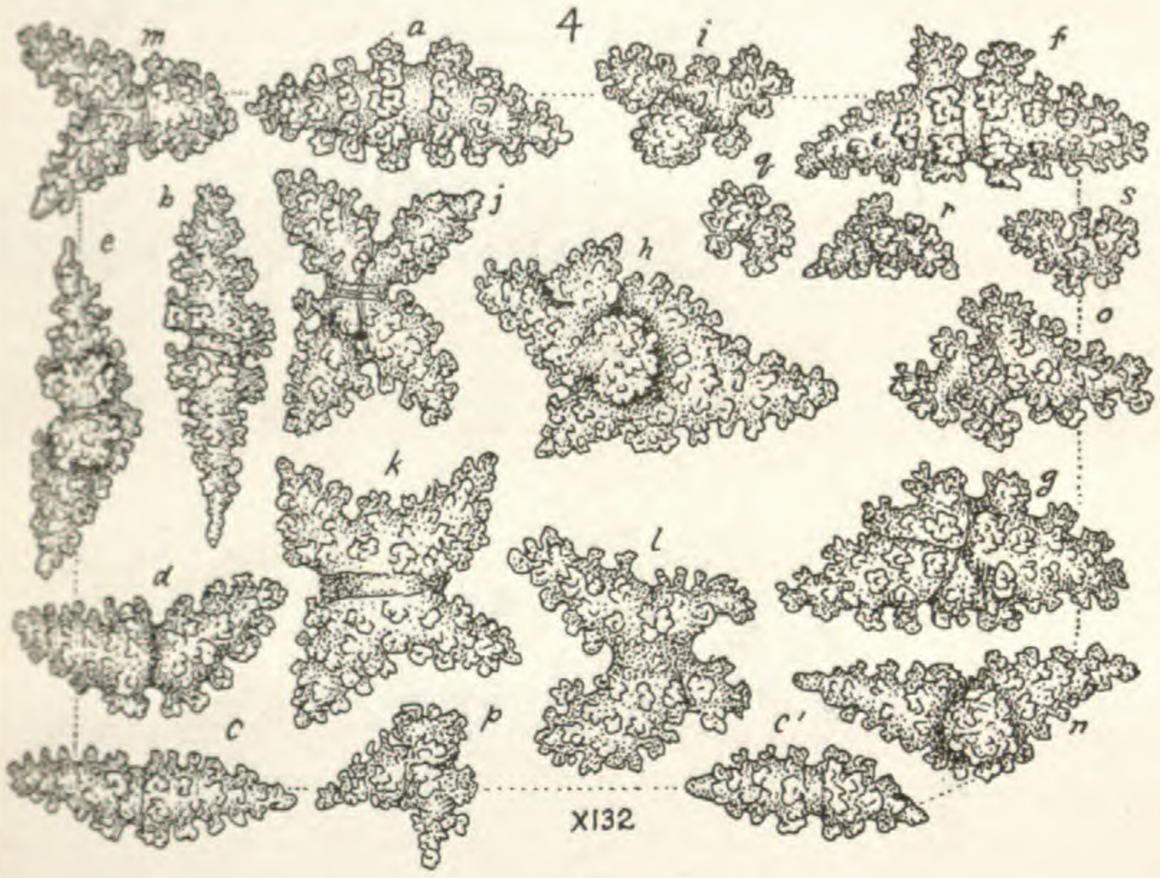
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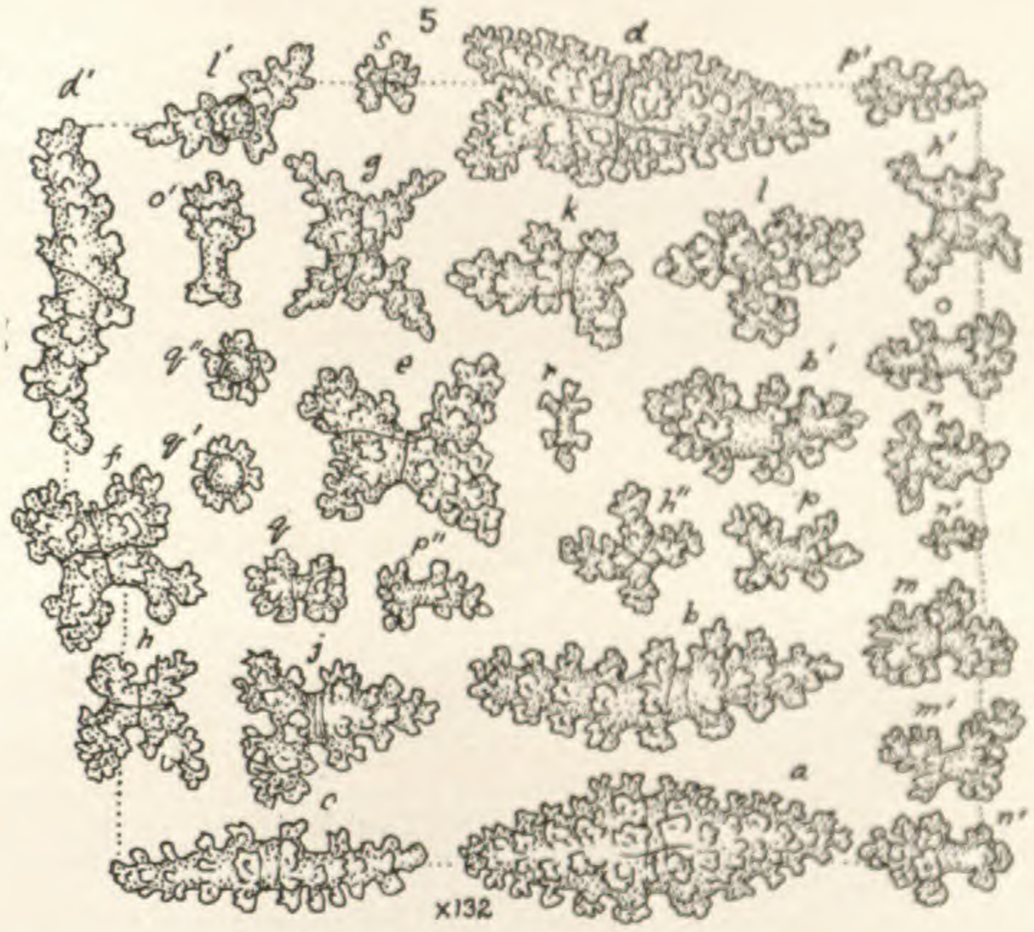
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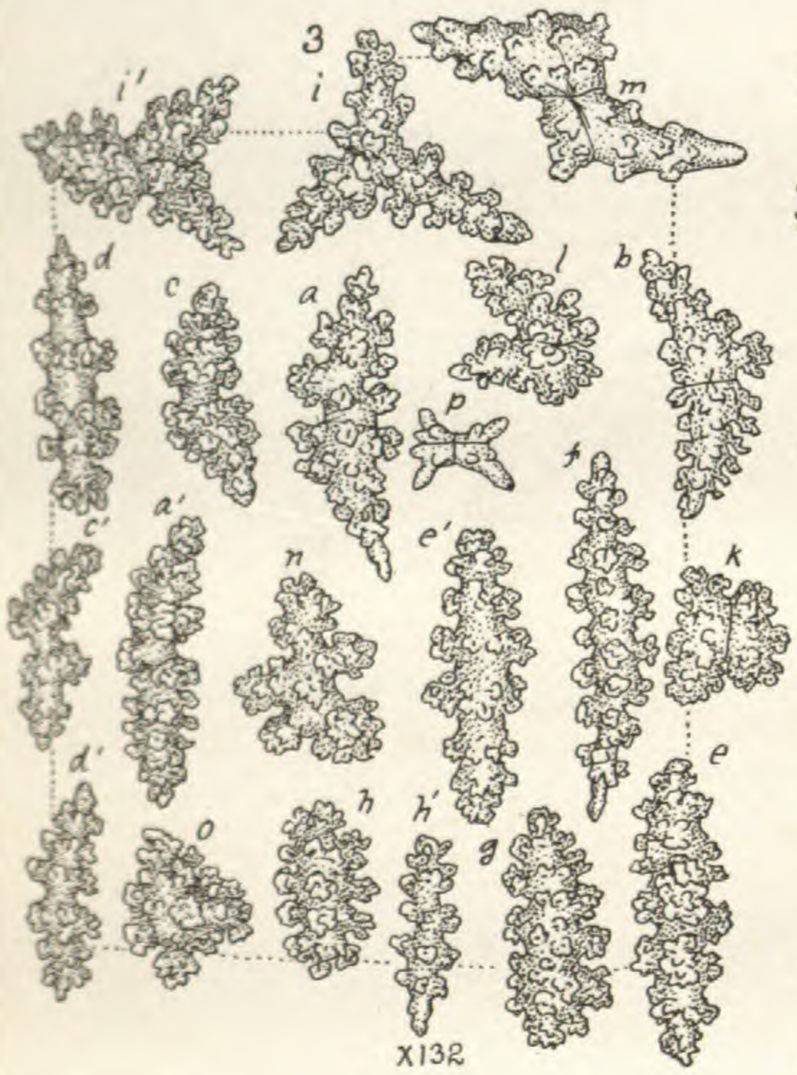
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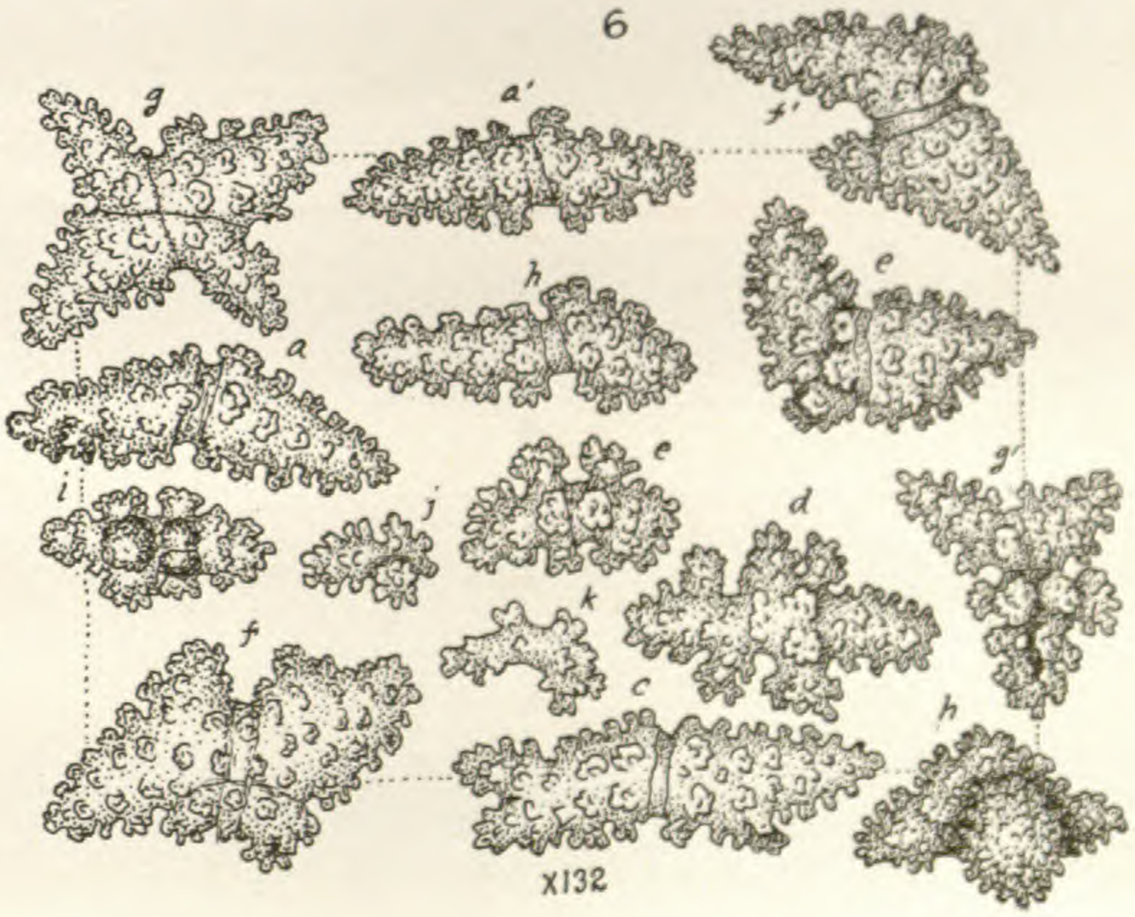
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PLATE XXXV.

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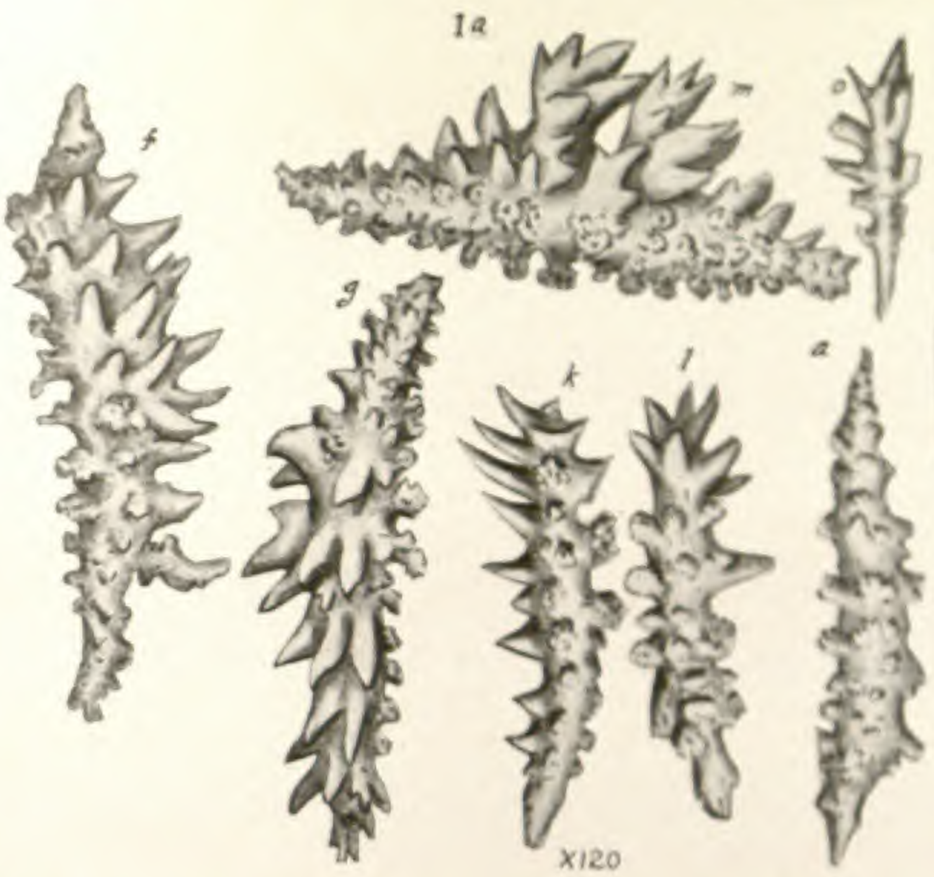

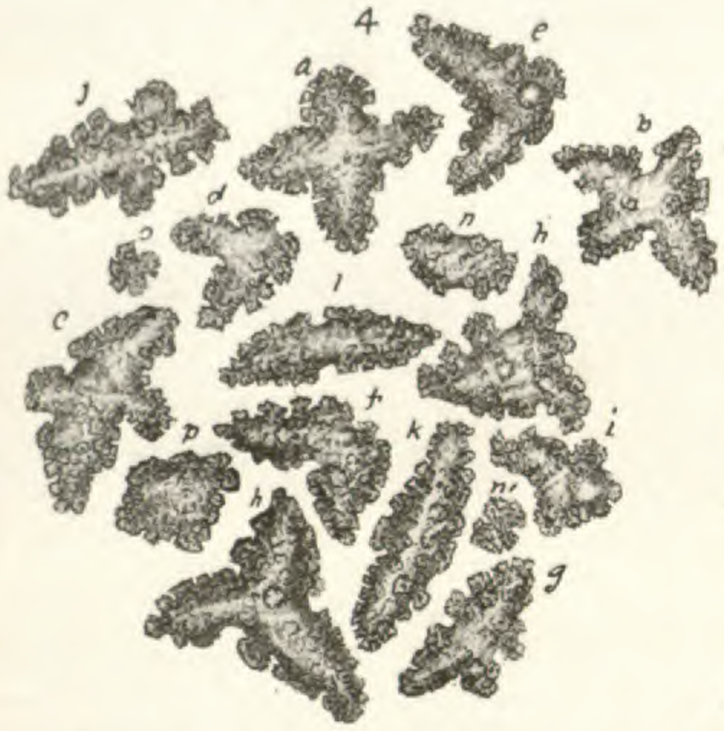

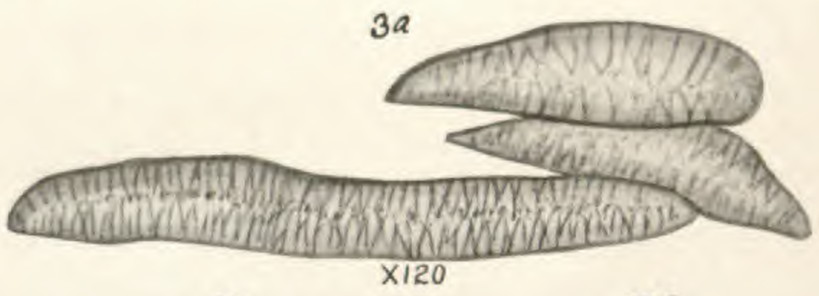

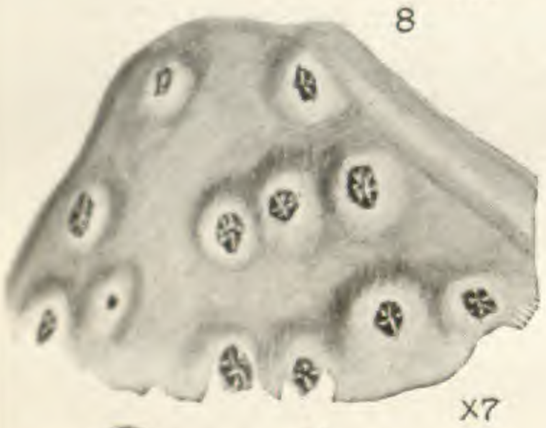

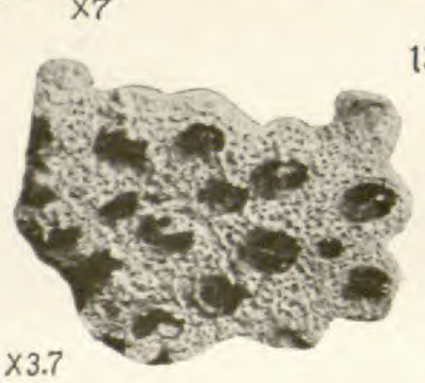

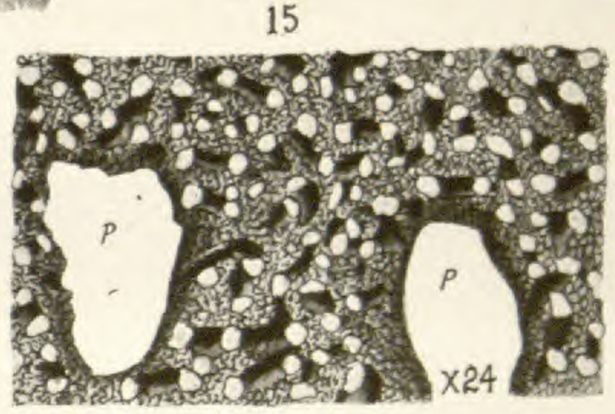

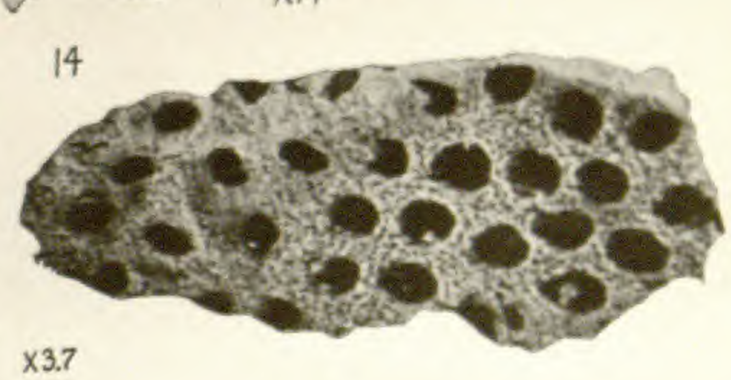

VERRILL: GORGONIANS OF BRAZILIAN COAST.

New Observations in Chemistry and Mineralogy

BY

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PLATE XXXVI

PHILADELPHIA
1912

NEW OBSERVATIONS IN CHEMISTRY AND MINERALOGY.

By George Augustus Koenig, Ph.D.

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1. A Sensitive Microchemical Reaction for Detecting Small Quantities of Cobalt Along with Much Nickel.

Basic Facts for the Method.—(*a*) In an ammoniacal solution of a cobaltosalt in presence of sal ammoniac a green color develops upon the addition of ammonium persulfate. The original solution being reddish-brown or brownish-red, there may be a time when the solution looks dark gray or even black through absorption-phenomena of light. Out of such a solution there soon falls a green precipitate and the liquid clarifies. The green precipitate consists of an aggregate of green crystals, rather olive-green mostly, but they may be any shade between bluish-green to emerald, to leek, to olive. The dimensions are microscopic; the shapes are various, but all conforming to monoclinic symmetry though frequently, through twinning, forms develop of very bizarre outlines. These crystals are not very soluble in pure water, nor in ammonia water. The precipitate has sometimes a lavender color and under the microscope contains granular, orange crystals. The latter may be obtained separately, as will be described. The green crystals will prove to be "praseocobaltioctamino sulfate"; the orange crystals to be "luteo cobaltidecamino sulfate." The lavender color is due to the presence of the isomeric "purpureocobaltioctamino sulfate."

(*b*) In the blue ammoniacal solution of a niccolosalt the addition of ammonium persulfate does not produce a change. Isometric, blue crystals may fall from the concentrated solution; or green, isometric quadruplets; or after several hours the crystals may turn brown-black, because they break up into niccoliditoxyhydroxyd, ammonia and ammonium salt. This change obscures the microscopic field of vision, but since it only occurs in time, it does not interfere with

the cobalt reaction. The forming of the bluish and greenish crystals has an influence upon the reaction only in so far as their mass lessens the concentration of the cobaltic molecules and causes different types of praseosalt crystals to form.

(*c*) A blue ammoniacal solution of a cuprisalt of high concentration throws out deeply blue crystals of cupraminosalt; the addition of persulfate causes sulfate of prismatic monoclinic type, while the nitrate is cubo-octahedral. Neither seems to interfere with the praseo reaction.

(*d*) In an ammoniacal solution of a manganosalt, ammoniumpersulfate gives black-brown peroxyhydroxyd. This can interfere by obscuring the field.

(*e*) Zinc and cadmium salts do not interfere.

Execution of the Method.—Concentration of the test liquid is very desirable, since the praseosalt is quite perceptibly soluble, but also because the green crystals will form at once. Let the precipitate, obtained by ammoniumsulfid in ammoniacal solution in presence of sal ammoniac, be the material for the test. We remove some of the paste with a steel spatula and dry it on the spatula over the flame in a few minutes. A small part of the dry material is then taken up with a borax bead and is roasted in the oxidizing flame, just within the point, so that the borax remains solid. One or two minutes will suffice for the oxidation, whereupon substance and bead are melted together. The color of the cooling bead will then tell whether nickel so predominates that the blue of the cobalt-glass is not visible. I do not advise oxidation of substance with nitric acid, making ammoniacal and then adding alcoholic solution of dimethylglycoxime, which gives a beautiful red precipitate with nickel-salts, because this reaction is too delicate. The action with the bead is in such a case both quicker and more decisive whether the praseo reaction for cobalt should be made or not. Let there be placed a quantity of dry precipitate not exceeding 5 milligrams in a clean porcelain crucible of the smallest size, add one drop of concentrated nitric acid and one drop of concentrated hydrochloric acid and evaporate to dryness, at waterbath temperature. The best shape of crucible is that of a cone. Hence I prefer to use a small conical cup, which I make from a large test-tube in the way familiar to glass-blowers. To the evaporated substance add a small quantity (1 or 2 mg.) of ammonium chlorid and then, with a fine pipette, one tenth of a cubic centimeter, *i. e.*, two drops, of strong aqua ammonia. If a precipitate of ferrihydroxyd or manganihydroxyd forms the two drops of liquid must be filtered without dilution. This can be done with a tiny glass funnel, whose stem is capillary. Such a one can readily be made by drawing out a thin glass tube and then widening one end. A tiny plug of filter-paper is placed in this enlarged end, which is then immersed in the liquid. By applying suction at the other end with the lips the entire liquid can be drawn into the capillary. After removing the plug, the widened end of the tube is taken between the lips and by forcing air into the tube a drop is easily transferred to the center of a clean glass slide. When the margin of the drop has been focused under a one-half inch objective, a fragment of a crystal of ammonium persulfate is placed in the

center of the drop by means of a suitable pair of forceps. Now bring the rim of the persulfate into focus and watch events. Bubbles of oxygen appear first; then a green fringe appears if the percentage of cobalt is not too small. A few seconds later the microlites of the praseosalt begin to float across the field of vision, owing to the currents produced by the escaping oxygen-gas. When I saw this phenomenon first, the concentration happened to be just right for the forming of the type of crystals which I call "bird on wing or butterfly type," and I was fascinated, for the things seemed to be animated, energetically starting upon the best exploitation of their ephemeral course. If no green microlites come up within two minutes the absence of cobalt is by no means proven. Such proof is brought only by the absence of crystals after the liquid has dried up. We see first, shooting from the rim toward the center, the colorless prismatic crystals of ammonium sulfate. In them are found imbedded the simple prisms of the praseosalt with a certain likeness to some forms of stained "bacilli." Not only the number of crystals but also their dimensions are decreasing with increasing dilution; but not without exceptions, owing, no doubt, to other attending or surrounding conditions. In a few cases large and well-formed crystals were obtained, when all present trace of material went into the forming of one crystal, instead of splitting up into many tiny ones. Some mineral localities furnish analogous facts, when the rarest elements are found in a few very large crystals. One remembers the enormous crystals of beryl, monazite, microlite at Amelia C. H., Va. In watching all of the phases in the drying up of a drop, one sees at the end a quick shooting of a kind of veil across the field; it is ammonium chloride and ammonium nitrate. This is not yet complete dryness and I have seen praseo crystals grow even then. But to see them one must remove the overlying veil. This can be done with a spray of ammonia water. The field clears up and must then be carefully looked over, meaning not only the field just in vision but the entire surface of the drop, which is usually from ¼ to ½ of an inch in diameter.

Since all the minerals which carry cobalt and nickel are decomposed by aqua regia, they may be subjected to the test for cobalt by this microscopic test, requiring only a very small trace of substance, very much less than is needed for the *Plattner* arseniation method, which, of course, is in itself a most excellent one. It is best to eliminate the arsenic by careful roasting of the mineral powder upon a surface of charcoal until the odor of arsenic is not perceptible, because experience shows that the presence of arsenic acid in the ammoniacal solution may prevent the praseo reaction, physically through the forming of a white fog or veil, chemically through the precipitation of nickel and cobalt together as white arseniate of indefinite forms. Sometimes it may happen that in presence of much copper the praseosalt falls out in such very small crystals that one fails to recognize them. In such cases allow the drop on slide to dry, then put one drop of concentrated ammonia water upon it. The minute microlites then dissolve, while the large copper-salt crystals remain intact, and as evaporation now proceeds

well-developed praseosalt-forms come up in astonishing abundance. This experience was gained in working with mohawkite and the kindred arsenids from Mohawk Mine, Mich.

Forms of the Praseocobaltioctaminosulfate.—The single crystals assume oftenest the *block-form* (Plate XXXVI, fig. 1, *a*, *b*, *c*, *d*, *e*) or the *staff-form* (fig. 1, *h*); the *book-form* (*g*, fig. 1) and the *paddle-form*, *f* (which is a combination of staff and block), are much less often seen. Owing to the rather deep color of even very small crystals it is not possible to determine the system of crystallization with certainty, but such tabular forms as *d*, fig. 1, leave little room for doubt that the system is *monoclinic*. Among the numerous twin forms the *saw-buck* or *chi* type is frequently seen. It is represented much magnified at *a* and *b*, fig. 3. Right angle or lateen crosses are not uncommon. A modification of the *chi* we find in the *tongs-type*, *f*, *f*, fig. 3, as well as in the large, ragged shape at *d*, fig. 2. The very bizarre composite forms which may be named the *bird*, *bug* or *butterfly* types, *b*, *c*, fig. 2, have undoubtedly the triplet saw-buck, *a*, fig. 3, as crystallographic base. The apparent curved lines as in the body portion of the butterfly, *b*, fig. 2, which look so very ungeometrical, or rather uncrystallographical, result from very rapid and interrupted growth. In the bug-form, *c*, fig. 2, the body represents a conical shape brought about by same interruption of growth and especially the legs are due to this same cause. The strange *digitate* type form *e*, fig. 3, as well as the *grass* type, *g*, *h*, fig. 3, are referable to combinations with the *angle-templet* type *c*, fig. 3, as base. The *burr* type is very common, *d*, fig. 3; it is a variation or rather combination of several groups of type *c*, fig. 3.

When cobalt-ions preponderate in test solution there form swarms of very dark-green, almost black, seemingly cubic, crystals. These probably are the products of nearly rectangular twinning, the base of which seems to be represented by *a*, fig. 2. Such prismatic forms as *e*, *g*, fig. 2, are incomplete terminally with strangely curved lines and are not understood by me.

Fig. 4 shows the microscopic picture which is obtained by dissolving 5 mg. of roasted mohawkite in 2 drops of hydrochloric acid and one drop of nitric acid; by evaporating the solution to dryness; by adding 5 mg. of ammonium chlorid and sufficient water to dissolve all; again evaporating to dryness, adding three drops of strong ammonia solution, stirring with capillary pipette, and transferring one drop to slide with about 3 mg. of ammonium persulfate. Liquid was intensely blue with an indefinable precipitate. Soon the lozenge and prismatic crystals of cupritetraminosulfate developed, intensely purplish-blue in color; they grew ultimately so large that they became quite visible to the naked eye. In measure as the crystals grew the field became more and more colorless, or rather lightly colored. When at last the preparation dried, the field showed pale greenish patches of nickel salt, much ammonium sulfate and ammonium chloride forming an arborescent veil over all. No praseo crystals were visible. A drop of strong ammonia water was allowed to run over the surface. The ammonia redissolved all but the copper salt. As evaporation proceeded the

picture developed as it is represented in fig. 4. Here *a*, *a*, designate the cupriaminosulfate; *b*, *b*, the nickelotetraminosulfate; *c*, *c*, the praseo cobaltioctaminosulfate. The relative dimensions of the three salts are fairly true to nature; the absolute dimensions are exaggerated. The copper salt is monoclinic, the nickel salt is isometric (cubo-octahedrons as b_2, b_3 and twins as b, b_1); they are at first pale blue but soon change to pale bluish-green through loss of NH_3. The nickel salt is the most soluble of the three salts in strong ammonia. Thin tabular crystals show red-purple color. The praseo cobaltisalt shows most of the types and is very yellow-green. The ions of the three metals are to each other, by analysis:

$$Cu : Ni : Co = 60 : 10 : 1.$$

Sensitiveness of the Method.—Two solutions were made, one containing 1.0 mg. nickel per c.c. and one containing 0.5 mg. cobalt per c.c. The burette containing the cobalt solution had narrow outlet and a thin edge, so that it made exactly 20 sharp drops to the cubic centimeter, hence one drop contains 0.025 mg. Co.

I. One drop of cobalt solution plus 2.5 c.c. of nickel solution holding 0.025 mg. Co + 2.5 mg. Ni or Co : Ni = 1 : 100 was evaporated in a conical glass tube, 2 mgs. NH_4Cl added, and three drops of strong ammonia used for solution; one drop to slide gave cubes of nickelamino salt and with persulfate great swarms of *praseo burrs* and *chis*. To make these microswarms, only 0.008 mg. Co was available.

II. One drop of cobalt solution plus 25 c.c. of nickel solution holding 0.025 Co and 25.0 mg. of nickel or Co : Ni = 1 : 1,000. One drop of this, containing one-fiftieth of the whole or 0.0005 mg. Co and 0.5 mg. Ni, was evaporated. Residue dissolved in two drops of ammonia and the whole transferred to slide gave with about 1 mg. of amm. persulfate three groups of praseo crystals of the *angle-templet* type. I should name this the *safe limit* of sensitiveness, though I have obtained prisms or bacilli with fewer ions than correspond to 0.0005 mg. through much experience in seeing and looking for the right thing in the right way. Such small prisms were obtained with 0.0003 mg. Co. They measure 70 micromillimeters in length and 1 to 2 m. m. m. in width. When the whole of the evaporated material of experiment II was dissolved in ammonia to purple color and a drop transferred to slide very numerous crystals of the burr and chi type were formed.

Note.—Most available samples of C. P. cobalt nitrate from reputed manufacturers gave the praseo reaction abundantly.

Preparation and Analysis of the Praseosalt and also of the accompanying Luteosalt.—It is stated above that by the action of persulfate upon an ammoniacal solution of cobaltosalt all the known amines of cobalt can be produced: the praseo and luteo amines result at low temperature, the purpureo, fusco and roseo amines in warm and hot solutions. The green salt falls out first and must be removed by vacuum filtration as soon as the liquid clears. The mother

liquor begins to throw out luteo salt in small octahedrons even before the complete clearing. Good results were obtained when 5 grams of $Co(NiO_3)_2.6H_2O$ and 5 grams of NH_4Cl were dissolved in 60 cubic centimeters of water. Thereupon mixed with 40 c.c. of concentrated ammonia water and 1.2 grams of ammonium persulfate stirred into the liquid, the resulting crystals were of the *block-twin* type because they formed rapidly. Mother liquor was displaced twice with 5 c.c. of water each time. When the third water was poured upon the crystals discoloration started in the top layer—a breaking up into the luteo form and into hydroxyd. The mother liquor standing over night in a cold room deposited considerable of the luteo salt. 1.484 grams of air-dry *green* crystals were obtained and 0.25 grams of the *orange* salt. Microscopic examination shows the green crystals to be contaminated with orange crystals.

Two analyses with 0.2 gr. each of substance gave:

Co	=	21.25	÷ (2 × 58.6)	= 0.1813 atoms
NH_3	=	26.86	÷ 17	= 1.5800
NO_3	=	0.99	÷ 62	= 0.016
Cl	=	5.60	÷ 35.5	= 0.1575
SO_4	=	27.81	÷ 96	= 0.2897
H_2O	=	17.49 (difference)	÷ 18	= 0.9717
		100.00		

Considering that the displacement of the mother liquor could not have been thorough (compare with above) we may assume all of 0.99 per cent. NO_3 to be part of extraneous $NH_4.NO_3$ and a part of the chlorine, corresponding to this, must be NH_4Cl. Deducting this extramolecular NH_3 from 1.58 atoms we have 1.548 atoms of intramolecular NH_3 left, hence $Co_2 : NH_3 = 1 : 8.5$. Also we get, assuming $Cl_2 = SO_4$, $Co_2 : (SO_4, Cl_2) = 0.1813 : 0.3604$, which is very close to 1 : 2, and thus follows for the analyzed material the formula

$$(Co_2(NH_3)_{8.5})(SO_4, Cl_2)_2.7H_2O.$$

The orange-colored crystals, though slightly soluble in water with yellow color are not decomposed by water. Hence they were freed from the mother liquor more completely, as the analysis clearly shows. Microscopically the substance was found to be homogeneous. The analysis with 0.1883 gram gives:

Co	=	21.88	= 0.1867 atoms
NH_3	=	30.70	= 1.806 "
SO_4	=	33.02	= 0.344 "
Cl	=	0.52	= 0.014 "
NO_3	=	trace	= ——
H_2O	=	13.88 (difference)	= 0.77 "
		100.00	

Hence $Co_2 : NH_3 = 1 : 10$ very nearly.

$Co_2 : SO_4 = 1 : 2$ not quite as nearly.

The orange salt is certainly a *decamine*. Its formula will be $(Co_2(NH_3)_{10})(SO_4)_2.4H_2O$. The calculated percentages for this formula are: Co = 21.26, NH_3 = 30.84, SO_4 = 34.81, H_2O = 13.06.

Since the *green* substance is shown, microscopically, to be a mixture of green and orange salt it is now possible to figure out the ratio between the two, namely, three Praseooctaminosulfate $3[(Co_2(NH_3)_8(SO_4, Cl_2)_2.6H_2O]$: one Luteodecaminosulfate $[Co_2(NH_3)_{10}(SO_4)_2.4H_2O]$.

Note.—These observations were made between April 1 and April 28, 1910.

2. Can Copper Ions Detach Themselves from Metallic Copper and Pass Through Space at a Temperature Considerably Below the Melting Point of the Metal?

This question arose under the following circumstances. I had determined the oxygen contained in refined copper in the usual way, namely, by heating about 20 grams of short pieces of the wire in a current of dry hydrogen within a bulb of hard glass. The wire had been sent from the smelter of the Quincy Mining Co. at Ripley, for a complete analysis, while Professor Fisher was to determine the electric conductivity. After removing the copper from the bulb I was struck by the intense ruby color of the glass. Something similar had been observed on previous occasions and notably when coils of copper wire-gauze which had been oxidized in preparing nitrogen gas, were reduced by hydrogen; but never before had the peculiarity of the phenomenon impressed me to such a marked degree. Many years ago, about the middle of the last century, Professor Max Pettenkoffer, of Munich, had advanced the theory that the copper-ruby of stained glass is due to the dissolution of elementary copper in the glass, and not to the forming of a cuprosilicate. The phenomenon is similar to the gold-ruby stain. This theory I have always believed in and have taught for forty years. It is probably universally believed in at this time. But dissolution means contact between the solvend and the solving agent. In the phenomenon before me there were certainly many points of contact between the glass and the many small pieces of wire. If this contact were avoided there would be no more loss of copper through its passing into the glass. My mind was working, then, solely on the improvement of the oxygen determination. To prevent that contact was not difficult. Instead of cutting short pieces of the thoroughly cleaned and polished test-wire, pieces two inches long were cut and these were made into a bundle or fascicle and tied with two pieces of asbestos cord, at a distance of one-half inch from either end. Made up in this fashion the bundle just fitted into the hard-glass combustion-tube so that there was a clear air space between copper and glass equal to the diameter of the asbestos cord (see fig. 5, Plate XXXVI). For two hours dry hydrogen was then passed through the tube while the copper was at visible red heat. The tube was then allowed to cool, the gas still passing. The result was unexpected indeed, *for there was the ruby-color in the glass wherever the glass was opposite the copper, both in front and behind the asbestos cord,*

but where the latter had been against the glass, there was a clear uncolored ring all round, as shown in fig. 6, Plate XXXVI. The presumption had failed. However, since the requirement of contact between solvent and solvend still existed, there were only two alternatives: either the copper contained a volatile copper-compound or the elementary copper must be able to tear itself from the wire surface and pass through the hydrogen atmosphere toward the glass. To gain insight into the mode of the action both alternatives must be considered. As to the first, reference must be had to the analysis of that special copper wire, and this analysis is as follows:

Copper	=	99.9843
Silver	=	0.0157
Arsenic	=	none
Iron	=	0.0072
Oxygen	=	0.0463
		100.0635

The excess in this analysis over 100 is due to the uncertainty inherent in weighing the electrolytic deposit of copper. The metal is very pure indeed; the presence of a volatile compound of copper is to be *absolutely* excluded.

It remains, therefore, to draw the conclusion that *copper particles can tear themselves from a polished piece of the metal; that these particles pass through the hydrogen atmosphere toward the glass; that the particles travel radially on the shortest path; that this phenomenon takes place at red heat, at the least 200° Centigrade below the melting point of copper.*

These experiments were made during the month of March, 1908. Owing to the pressure of other work the further pursuit of the matter was taken up only in November of the same year. In this second part of the investigation my aim was to establish the exact temperature at which the attractive force exerted by the glass as solvend was able to overcome the resistant force opposed by the cohesion of the copper molecules; for at this stage the facts seemed to point at a clear volatilization of copper *ad finem*, in the same way as water evaporates below the boiling point and even below the freezing point, so long as the force of diffusion is active in the surrounding air as solvend. Events proved this belief to be erroneous. Thirty-nine independent experiments were made during November and December of 1908. The results did not reveal to me the *unfailing* conditions under which the volatilization takes place, but merely that it certainly happens when the conditions are right.

In the following paragraphs a selected number of experiments only will be presented exactly in the words of my notebooks. A fresh tube was used for each experiment; all these tubes have been preserved and show now as well as they did at first.

Experiments I and II deal with adjustment of position of lever of the stop-cock at the burners in Erlenmeyer combustion furnace and the reading of platinum, rhodium thermocouple-galvanometer.

III. A bundle of copper wire tied with asbestos cord, which bundle had already been deoxidized in hydrogen, was so placed within the glass tube that its middle was exactly above middle of burner at the place where the thermo-couple had been. The couple itself lay one-eighth of an inch behind the rear end of bundle, not in contact with any of the copper, to avoid possible alloying. The action lasts from 10.55 to 1.00 P. M. The temperature is 370° C. *No color* is visible on the glass.

IV. Same bundle of wire, apparatus as before. Full heat lasts from 1 h. 40 m. to 3 h. 25 m., mean temperature is 580° C. No red color to be seen on glass.

VII. The same bundle of wire, which ought to be by now absolutely deoxidized is found to weigh 22.7520 grams (without the binding cord). It slides easily into the tube. Bundle is so placed that its middle is exactly between the flames of two adjacent burners. Heating lasts from 10 A. M. to 1 h. 25 m. P. M. Average temperature 660° C. The glass shows one ring of ruby color at the forward asbestos cord and very faint marks at the rearward cord. A faint white film is forward the ruby ring. The weight of the bundle is now 22.7435 grams, a decrease of 0.0085 grams or 0.0373 per cent. The tube shows slight sagging. Only a part of the decrease can have been copper, because the ruby is so very slight. Up to now the results are baffling and disappointing.

VIII. A new bundle of wire (Quincy No. 2), 10 pieces 2 inches long. The wire was rubbed and burnished with charcoal and chamois leather. The weight is 23.3869 grams. The middle of bundle is over first burner, second burner is only one-half open. The hottest part of the tube should be 590° C. Hydrogen passes about two bubbles per second. At first air only passes into tube because it was intended to carbonize and burn the cotton fiber in the asbestos before the beginning of the action proper. Thus the surface of the copper wire turned gray from surface oxidation. Action lasts from 11 h. 15 m. to 12 M. In this short time a fine red color has developed. But the color is ruby only in spots and patches. Far the largest part of the color is the pale red of metallic copper. The metallic particles seem to be projected against the glass as a spray of dust and the glass did not assimilate the metal for either lack of temperature or lack of time or both. What follows from the experiment? Is the startling result due to the previous oxidation? Must it be assumed that when hydrogen has taken away the oxygen, that the remaining molecules of copper are held together with less cohesion and that therefore they part from each other, *i. e.* *volatilize* and migrate to the surface of the glass tube?

Note.—The tube must have been hot enough to soften, because the asbestos cord left two well-developed grooves in the glass.

IX. Placed the bundle as in VIII. 1½ burners going. Duration of heat two hours after the copper has been oxidized for 20 minutes. Pyrometer shows 590° C. at end of heat. After cooling down the tube shows *no red*, neither copper nor copper ruby. Yet the bundle has lost 0.015 grams = 0.064 per cent. The wires are without blemish. The subject of the investigation becomes more and more elusive. *The oxidation hypothesis does not seem to be sustained.*

X. The same bundle, in which all the wires are now adhering to each other as if they were welded is again exposed as before. Oxidation lasts 15 minutes, using the compressed air. Duration of heat in hydrogen two hours; temperature 610° C. Loss of weight is 0.001 gram; but the development of *ruby color is rich*, especially near the cords, as shown in figure 7, Plate XXXVI. There is little dust copper. The direction of copper particles is chiefly *downward*. Is it because against the iron support the temperature is highest?

XI. Same bundle was oxidized without compressed air. The tube was simply inclined, whereby a light current of air was induced. Duration of heat 1 h. 10 m., temperature as before. There is slight show of ruby color in the lee of the forward asbestos cord. But some of the wires wear a roughness which means that the oxyd film has started peeling. Start heat again at one o'clock and keep up till 4 h. 30 m. Temp. steady at 600°–605° C. Loss in weight of bundle 0.0011, of which 0.0002 fell off in form of spangles, hence volatilized 0.0009 gram. Tube shows a patch of copper dust at *A* and slight ruby marks at *B* and *C* (fig. 8, Plate XXXVI). All this was visible after the first hour. The 2½ hours of second heat brought no change.

XII and XIII are enduring tests of 4 hours and 2 hours each at same temperature with same bundle. Loss in XII is 0.0002 gr., in XIII 0.0001 and there are traces of *red* in each case. Since this is limit of sensitiveness of balance, it must also be the limit of the experiment.

Conclusion from these Experiments.—(a) In order that ruby glass may form from the volatilization of copper ions in metallic copper, the latter must contain oxygen throughout its mass.

(b) The action is a maximum at the start.

(c) The lowest temperature is about 600° C.

XIV. A new bundle was made up of Quincy copper, sample 2. Wire rubbed and burnished with charcoal. Weight of bundle 22.9210. The tube is filled with hydrogen before turning on the flames. Duration of heat is 2 hours at temperature of 650°–670° C. The loss in weight is 0.0065 gram. The ruby-glass is well developed but different in relative location from any of the previous experiments. There is a broad, bright ruby band across the forward terminal of the bundle at *A*, reaching in fact ahead of the copper against the hydrogen current. At the rear terminal *B* the band is less intensely colored, is narrower and does *not* reach beyond the ends of the wires. Between the cords, at *C*, there is a very pale film of copper-dust (fig. 9. Plate XXXVI.)

XV. This is to be simply a question of loss in weight, with same bundle at same heat but in a new tube. Hydrogen current is lively. Duration of heat 3 hours. *Loss is nil* and there is *no trace of red* visible on the glass-tube.

XVI. A repetition of XV. Duration 1 hour 50 minutes. Loss in weight is 0.0015. *No coloration* on glass. Total loss by heating in hydrogen during 6 hours is 0.008 gr. or 0.035 per cent.

XVII. Same bundle oxidized in nearly horizontal position during 15 minutes

at red heat. Duration of heat in hydrogen 1 hour. Loss of weight 0.0055. gr. The tube shows a *pale ruby* color very uniformly spread except where asbestos touched.

XVIII. Same bundle in new tube, oxidized in horizontal position at red heat during 20 minutes; reduced in hydrogen during 1 hour 20 minutes. Loss = 0.0005. Tube shows no color in transmitted light, but *pale copper red* in reflected light from dust copper. Noticed that asbestos cord nearest to copper shows ruby color; first instance of the kind.

XIX. Same bundle in fresh tube, allowed to oxidize during 35 minutes at red heat. Reducing period in hydrogen 1 hour. Loss of weight is 0.0013. Development of *ruby*, *strong* and *even*.

XX, XXI, XXII reveal nothing special and hardly a trace of coloration.

XXIII. Same bundle. Oxidation as above during 45 minutes. Deoxidation during 1½ hours. Loss in weight is 0.0003 grams, development of *ruby is magnificent* between the cords, that is between *A* and *B*. Forward of *A* the color is very pale, while backward of *B* the ruby is stronger and shows besides two rings of dust copper, shown in figure with dots. Temperature was higher at *A* than at *B*. The strongest development is downward. The gas-current proceeds with the arrow (fig. 10, Pl. XXXVI).

Experiments XXIV to XXXV were made chiefly in order to find the most favorable conditions for oxidation, so that the film should not peel off. After each oxidation, however, the deoxidation was carried out without giving a decided ruby color in any of the ten cases. At the end of description of XXXIV my notebook says: "The mystery of the formation of the ruby is now more bewildering than ever before." The glass showed a brown smokiness, very pale, in the places where the ruby usually appears. Regarding the avoidance of peeling the finding pointed to a slow action at a temperature of 490° to 520° C. The placing of the tube horizontally with both ends partly or entirely open gives a slow exchange of the nitrogen inside with the air outside.

XXXVI. The material in this experiment comes from the Michigan Mine. The wire was drawn from ingots which I had melted myself from the chips of mass-copper. The material contains Cu = 99.8199; Ag = 0.1025; Fe = 0.0056; As = 0.0060; O = 0.0066. It is therefore exceptionally pure copper. Its electric conductivity is 100.7. The wire was rubbed off with chamois leather, but not burnished and scraped. The bundle was oxidized slowly during 5 hours and deoxidized during 2 hours at temp. 690°–710° C. *The display of ruby was great*, as seen in fig. 11, pl. XXXVI.

Drawing is one-half natural size. The current is with the arrow.

(*a*) A purple-colored ring surrounded by transparent ruby.
(*b*) Without color because protected by asbestos.
(*c*) Almost uniform mixture of ruby and dust-copper.
(*d*) Without color because protected by asbestos.
(*e*) Mixture of ruby and dust-copper.

(*f*) Very dark ruby ring surrounded by aureole.
(*g*) Blank glass space.
(*h*) A gray ring.
(*i*) A pale gray ring.
(*k*) A bright yellow film.

Note 1.—The rings at *a* and *f* are exactly above the ends of the wires. They suggest a maximum bombardment of copper particles. Why? Is perhaps the metallic cohesion less at the chipped ends than over the cylindrical surface?

Note 2.—The yellow sublimate is puzzling; it is *not* a compound of copper; too small a quantity of material to establish its nature.

XXXVII. The same bundle of wire was placed in a new tube; was oxidized at 460° C. during 1 hour; deoxidized at 690° C. for 2 hours. *No indication of ruby color whatever.*

XXXVIII. Repetition of XXXVI; only the surface of the wire was scraped with a knife edge and then burnished with charcoal and chamois leather. The ragged ends were cut smooth. Oxidation lasts three hours and deoxidation one hour. *Strong development of ruby* and a *yellow sublimate.* A replica of note 36, only there are no maximum bands *a–f* over the ends; the maximum is in the middle rather.

3. The Action of Sulfurdioxyd on Cuprisulfate Solutions in a Sealed Tube at Different Temperatures.

This investigation was brought about in March, 1910, by the activity of a Chicago party in offering stock of a company which was to leach a sandstone or other siliceous rock with dilute sulfuric acid. The rock is said to contain all its copper as carbonate and this was therefore an ideal condition. The solution was then to be treated in suitable tanks—lead-lined—with sulfur dioxyd under heat and pressure. The copper would all be precipitated as metal and the mother liquor could be used to leach out a fresh portion of rock. The question was not theoretical but rather practical at first and was submitted to me as follows: *Will SO_2 precipitate a coppersulfate solution completely and if so under what conditions?* There are four principal possibilities along the line of the following equations:

(*a*) $Cu(SO_4) + SO_2 + 2H_2O + \text{water} = Cu + 2H_2(SO_4) + \text{water.}$
(*b*) $2Cu(SO_4) + SO_2 + 3H_2O + \text{water} = Cu_2O + 3H_2(SO_4) + \text{water.}$
(*c*) $Cu(SO_4) + SO_2 + H_2O + \text{water} = Cu(SO_3) + H_2(SO_4) + \text{water.}$
(*d*) $2Cu(SO_4) + 2SO_2 + 3H_2O + \text{water} = Cu_2(SO_3) + 3H_2(SO_4) + \text{water.}$

Transposing these symbols into words we say: it is possible to form *native copper*, or *cuprite*, or *cuprisulfite*, or *cuprosulfite* according to temperature, pressure, predominance of sulfurdioxyd or its lacking.

The following experiments were made.

I. 0.5 gram of blue vitriol was dissolved in 25 c.c. of water. This gives 0.127 gram of copper in the 25 c.c. of liquid, or 0.5 per cent. The liquid was saturated with sulfur dioxyd gas at 20° C. about, and then sealed in a suitable glass-tube. Tube was then kept at 110°–120° C. in an air bath over night. Liquid looks colorless and a fine crop of copper crystals had formed, cubo-octahedrons and dodecahedrons. Upon opening the tube there was still a strong smell of sulfur dioxyd. After filtering the solution shows blue color and was precipitated by hydrogen sulfid. Result: 74 per cent. of copper had fallen out; 26 per cent. remained dissolved, notwithstanding the excess of sulfur dioxyd still remaining.

II. Repeat with all conditions alike except the temperature. This was kept at 135° C. over night. Solution had become colorless, with a crop of fine copper crystals. The ratio of precipitated copper to total copper was 93 : 100.

III. A saturated solution of blue vitriol was saturated with sulfur dioxyd and placed in air-bath. It exploded.

IV. Same saturated solution saturated with sulfur dioxyd was sealed up in tube and placed in air-bath at 2 P. M. When examined at 3 P. M. the thermometer showed 95° C.; *a large crop of dark, prismatic crystals had formed*, resembling spikes, and only a small quantity of metallic copper. In bright daylight the crystals are deeply blood-red and reminded me of chalotrichite or hair-ruby copper. A closer examination, however, did not confirm the first impression. The development of the faces at the pole did not agree with the isometric symmetry. It then occurred to me that the substance might be *cuprosulfite* $Cu_2(SO_3).H_2O$ mentioned by several authors.

Analysis.—In tube gives water, turns pale blue and leaves a black residue. A 1/100 normal solution of potassium permanganate acidified with nitric acid and brought into contact with the crystals becomes at once decolorized. This is good proof of sulfite. The salt would break up at the proper temperature into $2CuO + SO_2 + H_2O$. We should get from 224 parts of the salt 158 parts of CuO. Actually I obtained from 0.01529 gram a residue of 0.094 gram (weights are accurate to fifth decimal, because weighed on a very delicate button balance).

$$224 : 158 = 0.0153 : x; \quad x = 0.0099.$$

That is to say the analysis gives 0.0094 when the theory requires 0.0099. The microscope reveals small, granular, pale-bluish crystals sitting upon the blood-red crystals. They cannot be removed with water and are therefore *not copper sulfate* as I first thought. They are probably $Cu(SO_3).nH_2O$ a cuprisulfite? But their presence explains the discrepancy between 94 and 99 in the result of the analysis. The form of the red crystals is undoubtedly *monoclinic*. Ground form is a rather flat prism in combination with the clinodome and the ortho-pinacoid. The most frequent type is the pyroxene habitus; the two pinakoids in equilibrium, prism faces very narrow, and the basal plane; an acute hemi-

pyramid is rare. The thin crystals show yellow color. The faces are rough from the granular super-imposed pale-blue salt. The symmetry of the latter could not be made out.

While most interesting, the formation of red crystals was yet a side issue, since the object of the experiment had been to see whether SO_2 would be entirely changed into H_2SO_4 if it were deficient in regard to the cuprisulfate. On opening the tube the odor of sulfurdioxyd was strong. After filtering off the crystals, 1 c.c. of the mother liquor was titrated with potassium permanganate, and it was ascertained that only one-fourth of the sulfur dioxyd had entered into action.

V. Mother liquor from IV was saturated with sulfur dioxyd and sealed up in tube. The liquid, of course, is not saturated as to cuprisulfate because so much of the latter has been removed as cuprosulfite. Temperature was raised to 147° C. After 4 hours a coherent film of crystals of metallic copper and a few crystals of cuprosulfite had formed. The tube was then left in the oven for 20 hours longer, temperature ranging from 140° to 160°. The color of the liquid is still *blue* and the smell of the dioxyd very strong. 1 c.c. requires 7.2 c.c. of permanganate against 16.8 c.c. before the action—57.2 per cent. only had been active.

VI. A sealed tube containing liquid saturated with both copper-vitriol and sulfur dioxyd was placed in upright position in a glass cylinder filled with water in order to enable observations to be made more conveniently. The temperature was raised slowly, the water being agitated and mixed with a long thermometer. With rising temperature the color of liquid changes more and more toward emerald-green. At 75° C. a darkening sets in, owing probably to some optical interference phenomenon. At same time dark spots form on the surface. These increase in size and after a while detach themselves and slide to bottom of tube. Each wart is a radiating group of cuprosulfite crystals. At 90° C. crystals of metallic copper begin to form. At 93° C. the cylinder was broken and experiment came to halt. The crystals of the warty groups were much smaller than those obtained in previous operation.

Conclusions.—First: Of the four possibilities two were realized *certainly*, namely, *a* and *d* and *perhaps c.*

Second: The action of sulfurdioxyd upon copper sulfate solution belongs to the "mass" phenomena; it is incomplete both ways.

4. On Sulfurdioxyd as an Oxidizing Agent by Preying upon its Own Oxygen.

The following observations were made in January, 1911, and as far as my reading goes they are new. The impetus of the experiments came through objection of U. S. Patent Office to one claim in my application for a patent on improvements in the leaching of certain vanadium ores from Colorado, because a patent issued to A. Fleck *et al.* contains the claim that sulfurous acid will extract the sandrock from certain localities. There are two localities at present known;

at the one the sandstone carries essentially carnotite, at the other it carries roscoelite with only a trace of carnotite. Fleck was working with the carnotite variety. Carnotite is a potassium uranyl vanadate; sulfurdioxyd being a deoxidizing agent reduces the vanadic radical to vanadyl, becomes itself sulfuric acid and this latter then forms potassium-uranyl-vanadyl sulfates. This is quite rational. But with roscoelite it is different. This mineral is a potassium-aluminum-vanadyl silicate. How should a weak acid such as sulfurous acid decompose it, when sulfuric acid of 20 per cent concentration requires a temperature of 200° C. and a pressure of 20 atmospheres to effect the decomposition? Chemistry, however, is not yet an exact science: one cannot foretell absolutely what will happen from certain given premises. With this in mind the experiment was made and the expectation was negatived.

I. 100 c.c. of distilled water, standing in a glass-cylinder in snow were saturated with sulfurdioxyd, meaning that the gas passed into the water until the bubbles rose without loss of volume. The gas was generated by sulfuric acid from sodium bisulfite; also the gas was fresh from spray by filtering it through 4 inches of cotton, and 2 inches of water. The roscoelite ore contains roughly 83.5 per cent of quartz grains; 11.0 per cent of roscoelite and 5.5 per cent of dolomite. 1.0 gram of this ore was transferred to glass-tube with 60 c.c. of the sulfurous liquid, filling two-thirds of the tube. There was a strong effervescence from carbon dioxyd escaping. A *perfect sealing* of the tube in the blast-lamp was obtained after the tube had been sitting in the snow outside at a temperature of minus 16° C. until the liquid was frozen. The object was, in charging as stated, to give the sulfurdioxyd an overwhelming mass and therefore the best chances of winning the fight. The tube went into the air-bath at 9.20 A. M. At 10 A. M. the temperature had become steady at 205° C.; the action was kept up until 6 P. M. At times the temperature rose to 213° C. owing to lessened gas consumed in the laboratories. Since lamp-light interferes with the colors the tube was not examined until 9 o'clock the following morning. The liquid showed a *pale-blue* color. The residue showed dark colored sand, specks of bright yellow substance (possibly uranyl sulfite?) and large, shiny, globular, solidified drops of *sulfur*. Of this latter element 0.382 gram was recovered; a part of sulfur was lost by evaporation with hydrofluoric acid and sulfuric acids. The liquid extract yielded 2.52 per cent V_2O_5. Since the total in the ore was 3.43 V_2O_5 it followed that the efficiency of extraction had been about 73 per cent. But the work was *not done by* SO_2, for the metals were in the filtrate entirely as *sulfates*, the sulfur dioxyd had merely furnished the materials. The action must have been in line of the scheme $3SO_2 = 2SO_3 + S$. SO_2 oxidized itself by throwing out sulfur, a very unlooked-for result.

II. Two grams of ore were sealed up with 50 c.c. of saturated sulfur dioxyd solution (1 c.c. of the solution requires 17.1 c.c. permanganate). Action in bath, 1½ hours. Temperature average 147° C., maximum 164° C. Examination on the following morning disclosed that no visible action had taken place. Tube

replaced in air-bath and kept at temperatures ranging between 180°–194° C. for 6¾ hours; a small quantity of floury sulfur is now seen floating on liquid, roscoelite is barely attacked. Following morning began heating air-bath at 8 h. 50 m. Temperature brought up rapidly and kept at between 235° C. to 240° until 3 h. 20 m.; that is 6½ hours. Color of liquid is strongly greenish-blue; the dark roscoelite particles have disappeared, the quartz sand is nearly white. Sulfur is in many drops (liquid); there are *no yellow* specks. Attempt to unite many sulfur drops by replacing tube into oven, without success. After cooling, opened the tube and filtered the content. 1 c.c. of filtrate requires 3.0 c.c. of permanganate; 17.1 c.c. − 14.1 c.c. have been used up in action or 82.5 per cent of the SO_2 has been changed into sulfur and sulfuric acid. The entire filtrate was then kept boiling until SO_2 was expelled and then the sulfates were precipitated by $BaCl_2$, resulting in 7.8842$BaSO_4$. To this must be added 0.303 $BaSO_4$, which was recovered from the residue, having been stored therein as $CaSO_4$ (originally dolomite). From the residue was recovered 0.5510 gram of elementary sulfur by volatilizing all the quartz with hydrofluoric acid. 8.1872 $BaSO_4$ give 1.1255 grams of sulfur, hence follows elementary sulfur: sulfuric sulfur = 0.551 : 1.1255 = 1 : 2.04. This tallies exactly with the formula

$$3SO_2 = S + 2SO_3.$$

The question now arises: does the vanadyl play any special rôle in the action of the sulfurdioxyd, or does the same action take place for any decomposable silicate, no matter what the bases may be? The following two experiments give an affirmative answer to the second query.

III. One gram of black slag finely ground was sealed up with 50 c.c. of sulfurous solution. Slag came from cupola-furnace of copper-smelter and is high in iron. Slag decomposes rapidly at 235° C., throwing out silica of very voluminous character. Sulfur is so intimately involved in this silica that it does not show. After filtering, drying the residue, eliminating the silica by hydrofluoric acid, and finally dissolving the sulfur in redistilled carbon disulfid; on evaporation of the latter *0.202 gram pure sulfur* was recovered.

IV. Orthoclase represents that type of polysilicate which is not decomposable readily by sulfuric acid. 1.0 gram of finely ground orthoclase was sealed up in tube with 40 c.c. of the sulfurous solution. Tube was kept 18 hours at temperature ranging between 230° and 250° C. Again the residue showed barely the sulfur to naked eye; under microscope it is easily seen. The filtrate—after expelling sulfurdioxyd—which had come down to 2.2 c.c. permanganate per cubic centimeter, 1.5117 of $BaSO_4$ was obtained. This gives 0.519 gram of SO_3 or 0.208 of sulfur as the product of the action in forming aluminum sulfate and potassium sulfate from the orthoclase.

Conclusion.—"It is experimentally proven that sulfurdioxyd in aqueous solution and in presence of a silicate which is decomposable by sulfuric acid—and at a

temperature above 200° C. in a sealed glass-tube—will break up into sulfuric acid and sulfur according to the equation"

$$3SO_2 + aqua = 2H_2(SO_4) + S.$$

5. On Aurobismuthinite, *spec. nov.*

The material appears as a fragment of a plate with nearly parallel sides; must have been the complete filling of a fissure three-eighths of one inch wide; one of the parallel faces looks like a black slickenside; there is calcite associated with the mineral. Those who sent me the specimen with the request for information as to whether the gold in it could be extracted with mercury, have not responded to my request for its locality. The mineral is a granular massive with numerous cleavage planes. These appear to be prismatic, like those of bismuthinite and stibnite. The color of the fresh fracture is light gray, like metallic lead. The mineral is soft and mild, somewhat smearing under the pestle.

In the open tube it gives much sulfurdioxyd and a yellow sublimate on either side of the substance. No reaction for tellurium. On charcoal is given a soft, white metal, which on the cupel gives a fine gold button with indication of some silver. Gives strong reaction with potassium iodide and sulfur (bismuth). Borax bead indicates trace of copper. Rubbing together with mercury does *not* extract any gold.

The mineral aggregate is very homogeneous. 0.3073 gram gave 0.3430 $BaSO_4$; 0.2380 Bi_2O_3; 0.0368 Au; 0.0095 AgCl.

Bi	= 69.50 : 210		= 0.3310	
Au	= 12.27 : 197.2		= 0.0622	.4039 = 1.0
Ag	= 2.32 : 2	× 107.66	= 0.0107	
S	= 15.35 : 32		= 0.4800	.4800 = 1.2

leads to the formula $(Bi, Au, Ag_2)_5S_6$.

The view that the normally trivalent gold should replace the equally trivalent bismuth has much in it that is pleasing to me, notwithstanding that one is normally isometric and the other hexagonal. If one does not like the ratio 5 : 6 one can assume here exactly what is assumed by many for pyrrhotite, namely, that the latter is really FeS and is merely mixed with a varying quantity of pyrite, while in present instance *m* aurobismuthinite $(\dot{Bi}, \dot{Au}, \dot{Ag_2})\dot{S}$ is admixed with *n* bismuthinite Bi_2S_3. In fact the presence of the cleavable prisms might be cited in support of such a view, although the color of the two is exactly alike. There is a third view possible. We may consider gold and silver as an alloy *molecularly* dissolved within bismuthinite and *not* united with sulfur. This view is supported by the fact that bismuth is to sulfur as 1 : 1.45, as 2 : 2.9, very nearly 2 : 3 which is bismuthinite. Whichever view be taken, the new substance is a very interesting individual and deserves a special name. *July, 1908.*

6. On Stibiobismuthinite.

The material was sent by Mr. H. P. Bowen, a former pupil, in the winter of 1906. The locality of occurrence is the neighborhood of Nacozari, state of Sonora, Mexico.

The specimen appears as an aggregate of large prismatic crystals of the stibiobismuthinite and granular chalcopyrite. Some crystals are two inches long by one-half inch wide; they look more like sibnite than bismuthinite both for color and dimensions. However the crystals present the usual polysynthetic structure and cleavage.

In closed tube the mineral melts easily and gives a strong sublimate of sulfur, a slight red sublimate of antimonyoxysulfid and a slight sublimate of metallic antimony. In the open tube strong white fumes of antimony trioxyd, and even here a slight sublimate of sulfur. With potassium iodid on charcoal strong *red* film of bismuth oxyiodid. 0.3633 gram gave 0.3160 BiOCl and 0.0411 Sb_2S_3.

Bi =	69.90	: 210 =	0.3330	0.3995 = 1.00
Sb =	8.12	: 122 =	0.0665	
S =	21.92 (by difference)	: 22 =		0.6869 = 1.72
	100.00			

The nearest ratio with whole numbers is 4 : 6.88, which makes the formula $(Bi, Sb)_4S_7$.

The strong sublimate of sulfur in both open and closed tubes indicates the presence of a higher sulfid than 2 : 3, as in bismuthinite.

7. On Crystallized Seladonite.

The specimen was sent by Mr. Grant, a former pupil, to Professor Seaman, to whom I am indebted for it. It is said to come from near Vail, Arizona, about 4 miles east of that town, where it comes in basalt and basaltic tufas. The seladonite is associated with reddish gray calcite. Even when examined with the lens, the seladonite appears to form soft masses without distinct shape. When such a mass is digested with water or only stirred up with the liquid; the mass disintegrates into minute green prisms. This enabled me to get the material to a high state of purity, since the only other mineral present is calcite. The prisms are 0.01 mm. long and 0.0005 broad. They show pyramidal development; the outlines are not sharp, apt to show undulation. There is also a tabular type. The color of these prisms and plates is pale olive green under water, bluish-green in air.

The *true hardness* cannot be ascertained; the apparent hardness is that of any felted or pulverulent substance. The color of the large aggregate is that peculiar blue-gray-green also known as "seladon green."

B. B. In tube gives water and turns brown. With fluxes reacts only for iron. Acted on slowly by concentrated hydrochloric acid. Fuses to glass at yellow heat.

For analysis 0.245 gram of pure material was available. Was used in three portions. 0.1003 gave loss by ignition 0.0064 gram; silica 0.0549 gram; ferrioxyd and alumina 0.0270 gram; magnesium pyrophosphate 0.0160 gram.

0.0413 gram was decomposed with sulfuric and hydrofluoric acids in atmosphere of carbon dioxyd. 0.3 c.c. permanganate solution were required.

0.1003 gave potassium sulfate 0.0137 gram; this included a trace of sodium sulfate.

SiO_2	=	54.73 :	60	= 0.9122	
Fe_2O_3	=	13.44 :	160	= 0.0840	0.1581
Al_2O_3	=	7.56 :	102.2	= 0.0741	
FeO	=	5.30 :	72	= 0.0736	0.2963
MgO	=	5.76 :	40	= 0.1440	
CaO		none			
K_2O	=	7.40 :	94	= 0.0787	
H_2O	=	6.40 :	18	= 0.3555	
		100.59			

The ratio is very nearly $RO : R_2O_3 : SiO_2 : H_2O = 2 : 1 : 6 : 2.24$. Assuming that one molecule of water is of basic character, the formula transforms into a clear metasilicate

$$(K_2H_2Mg, Fe)_3(Fe_2Al_2) \cdot (SiO_3)_6 + 1.24(H_2O).$$

8. On Natrojarosite from New Locality.

The material was collected during the summer of 1910 by Professor Seaman at the Mina San Toy, Santa Eulalia, Chihuahua, Mexico; he placed it in my hands for investigation.

The material appears in association with selenite and mimetite, as well as some one as yet not identified silver mineral, because the aggregate assays up to 50 ounces of silver to the ton. Under the lens the natrojarosite forms an aggregate of straw-yellow scales, with strong silky luster. The scales are lying loosely together and resemble closely the scaly dust on the wings of a butterfly. Like the latter, they stick to the finger at the gentlest touch. Cacoxenite was the nearest mineral suggested to my memory. With one-half inch objective the scales appear as well-defined *hexagonal plates*. The edges do not show any faces. The habitus is altogether holohedral. Herein they differ from those described by Hildebrand & Penfield[1] from the east side of Soda Springs Valley, Nevada. The latter crystals are rhombohedral, same as the normal jarosite and alunite.

B. B. Same reactions as those of normal jarosite.

0.5000 gram gave $0.2547Fe_2O_3$; $0.4423BaSO_4 = 0.1517SO_3$; $0.056(K, Na)Cl$; $0.0525K_2PtCl_6$.

0.2554 gram mixed with PbO gave at red heat a loss of 0.0309 H_2O.

Insoluble	=	0.69			
Fe_2O_3	=	50.94 :	160	= 0.3184	3.57
SO_3	=	30.43 :	80	= 0.3804	4.263
Na_2O	=	4.20 :	62	= 0.0677	0.0892
K_2O	=	2.02 :	94	= 0.0215	
H_2O	=	11.73 :	18	= 0.6517	7.3
		100.01			

[1] Am. J. Science, XIV, fourth series, pp. 211 and following.

Formula is $(Na, K)_2SO_4 . (Fe_2(SO_4)_3) . (HO)_{12}$ + basic ferrisulfate $(Fe_2O_3)_{0.57}(SO_3)_{0.26}(H_2O)_{1.3}$.

9. On Mimetite from Santa Eulalia.

This is the companion of the natrojarosite at Santa Eulalia. It occurs in small six-sided prisms with pyramidal poles. The faces are uneven; the color is honey-yellow.

The following analysis was made under my direction by Mr. Dan Newkirk, an advanced student. The material had been carefully picked over. 0.2800 gram gave: $0.0285AgCl$ = 2.51 per cent Cl; $0.2717PbSO_4$ = 70.0 per cent Pb; $0.0855Mg_2As_2O_7$ = 22.60 per cent As_2O_5. 2.51 per cent of Cl require 7.3 per cent Pb to form $PbCl_2$; hence 70.0 − 7.3 = 62.7 per cent Pb must be PbO = 67.6 per cent. Therefore the composition of mineral is

PbO	=	67.6 : 223 = 0.3031
As_2O_5	=	22.6 : 230 = 0.1000
$PbCl_2$	=	9.8 : 278 = 0.0352
		100.0

Hence $3.03PbO . As_2O_5 + 0.35PbCl_2$ or $3 . (Pb_3(As_2O_4)_2) . PbCl_2 + 0.09PbO$. The summing up of the results to an exact 100 must be ascribed to accident. Lead is slightly in excess, namely 0.67 per cent.

EXPLANATION OF PLATE XXXVI

Fig. 1. Simple microscopic crystals of praseooctaminosulfate. Forms *a*, *b*, *c* show normal development; *d* shows tabular development parallel to clinopinakoid; the positive and negative hemidomes and orthopinakoid produce the pseudohexagonal outline; *e* is a partly developed form; *f* a combination of forms; *d* and *h* the so-called paddle form; *h* the staff-type overwhelmingly prismatic; *g* the book-type.

Fig. 2. Bizarre twin forms: *a*, nearly rectangular twin producing the block-type; *b*, the butterfly type; *c*, the bug type; *d*, the tongs type; *e*, *f*, *g*, incomplete twins.

Fig. 3. *a*, *b*, the chi or saw-buck type; *c*, the angle-templet type; *ff*, the tongs type; *d*, the burr-type; *e*, the digitate-type; *h*, *g*, the grass-type.

Fig. 4. Microscopic figure prepared from Mohawkite. a_1, a_1, a_2, a_3, a_4, a_5, a_6 are blue, monoclinic combinations of cupritetraminosulfate; *b*, b_1, b_2, b_3, green, isometric combinations of nicolotetramino chlorid; *cccc* . . ., olive-green monoclinic combinations of praseo-cobaltioctaminosulfate.

Fig. 5. Glass-tube with a fascicle *a* of copper wire tied by two asbestos cords, *b*, *c;* in sectional view.

Fig. 6. The glass-tube after the action. *a b* are the blank spaces which had been protected by the asbestos. Between these two the glass is deeply stained with the ruby color, forward of *a* less deeply and rearward of *b* least stained.

Fig. 7. The mixed effect of ruby stain and superficially attached copper-spangles. The dots, representing spangles are not of the same color in reality, the spangles are of the faint pink color as the wire in Fig. 5. Exp. X.

Fig. 8. Faint and partial staining as produced in Exp. XI.

Fig. 9. Wire-fascicle in outline. Very broad blank rings where protected by asbestos cords. At *a* strong ruby stain projecting forward of wires, at *b* ruby stain-band less strongly marked, at *c* a faint film of copper-spangles. Exp. XIV.

Fig. 10. Magnificent development of ruby stain between the cords, a faint stain forward of *a* and two rings of spangles rearward of *b*. Exp. XXIII.

Fig. 11. Result of Exp. XXXVI. *a*, a purple colored ring surrounded by ruby stain; *b*, blank glass protected by asbestos; *c* uniformly mixed ruby stain and spangle-copper; *d*, blank glass; *e*, mixture of ruby stain and spangles; *f*, very dark ruby stain surrounded by aureole; *g*, blank glass; *h*, a gray ring; *i*, a pale-gray ring; *k*, a bright yellow ring not given in color.

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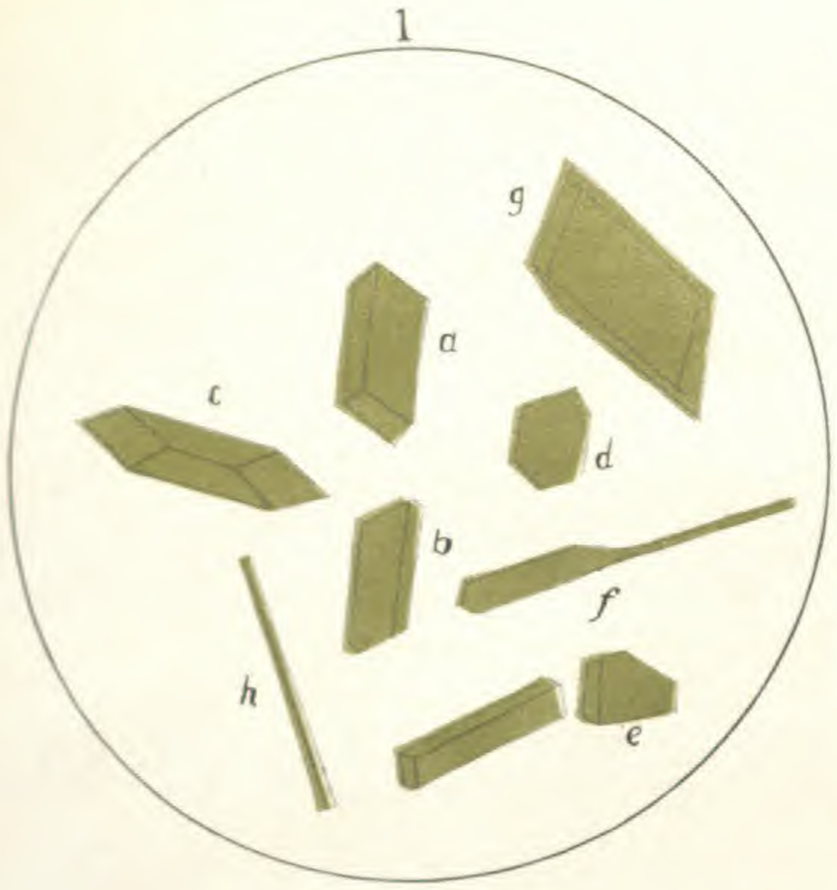

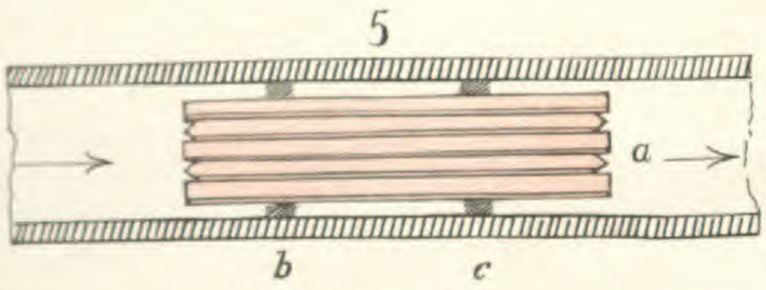

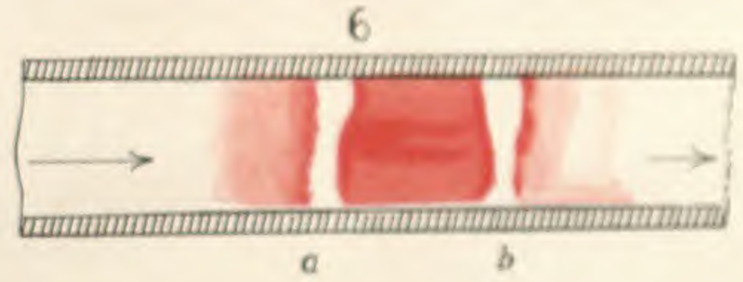

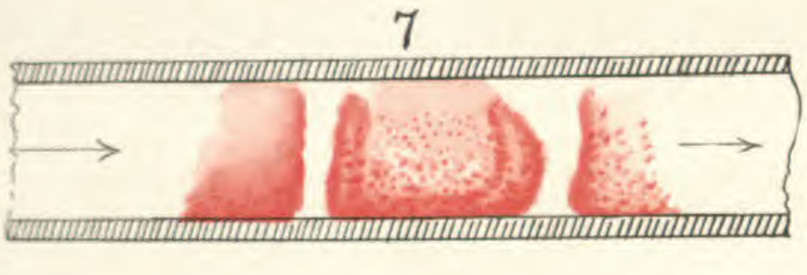

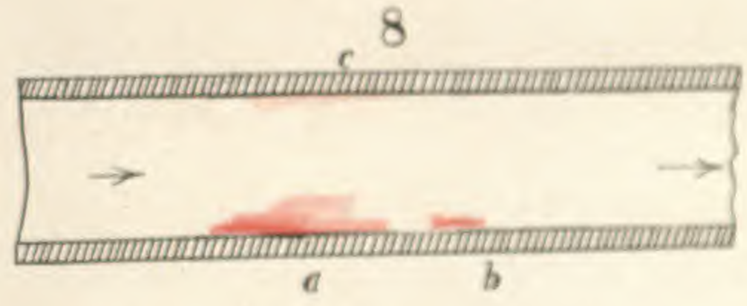

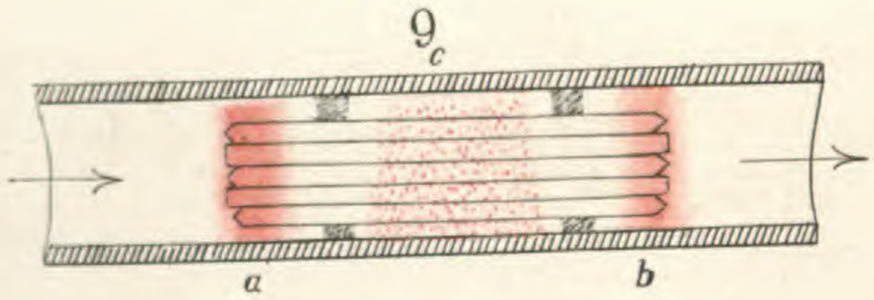

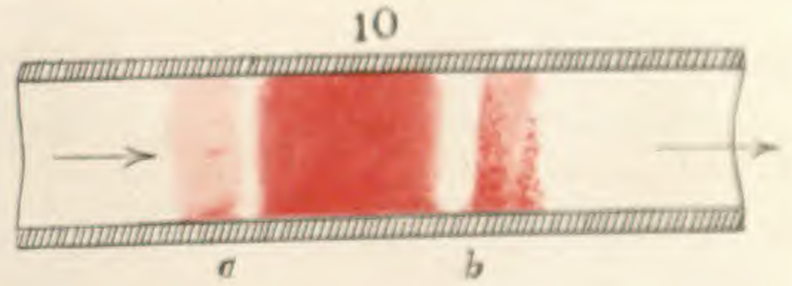

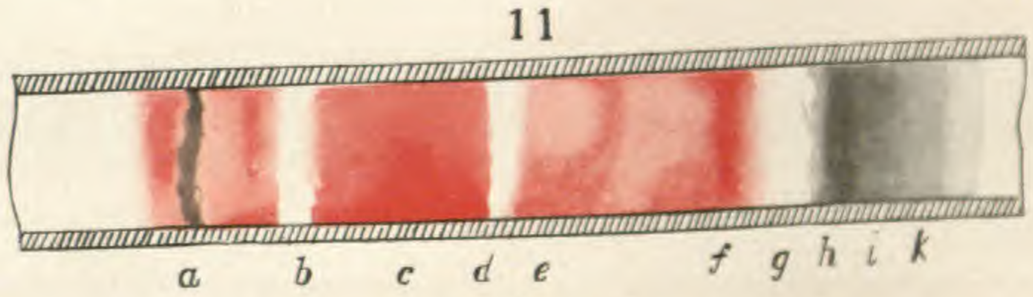

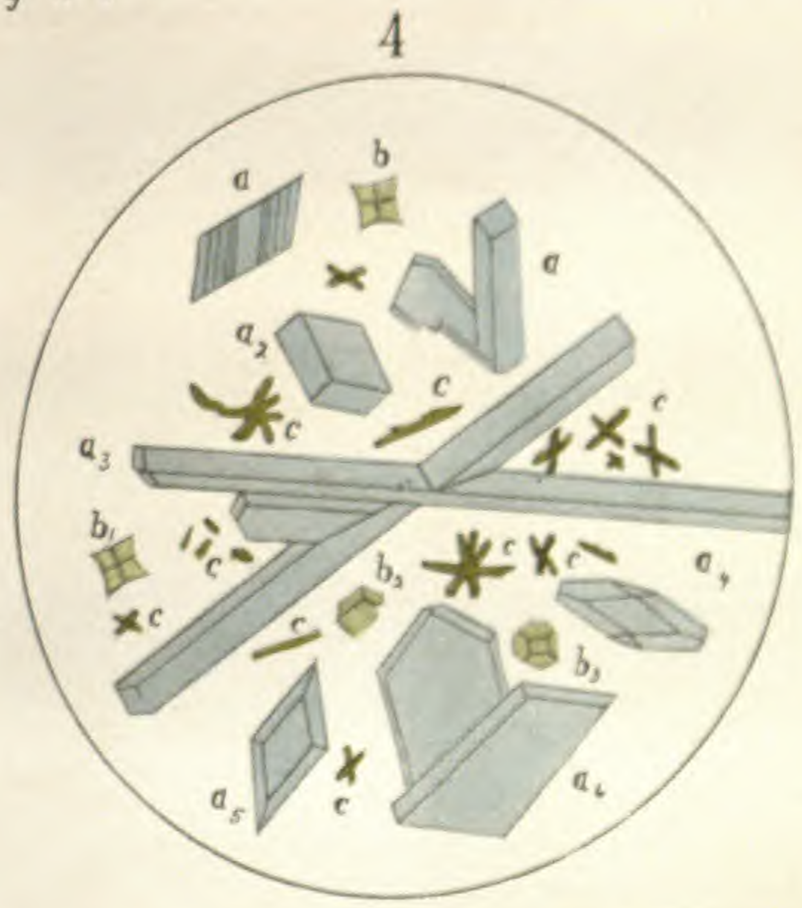

KOENIG: NEW OBSERVATIONS IN CHEMISTRY AND MINERALOGY.

A Study of the Variation and Zoogeography of Liguus in Florida

BY

HENRY A. PILSBRY, Sc.D.

PLATES XXXVII–XL

PHILADELPHIA
1912

A STUDY OF THE VARIATION AND ZOOGEOGRAPHY OF LIGUUS IN FLORIDA.

By Henry A. Pilsbry, Sc.D.

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I. INTRODUCTION.

Students of mollusks, as of many other animals and plants, have often to deal with species, or groups of closely related species, showing a very wide diversity in color and pattern. While in the majority of molluscan species the color and pattern are constant within moderately narrow limits of variation, there are also many species in which great variation occurs among individuals of a single colony. The species of *Oliva* and *Umbonium* among marine, and *Liguus*, *Partula*, *Achatinella* and *Amphidromus* among land snails are conspicuous examples.

Little has been done by conchologists towards the interpretation of "variable" races. No distinction has been made between the omnipresent "fluctuating variations" of relatively stable forms and the striking diverse patterns of the others. Experimental work along Mendelian lines with plants in the last few years has shown that a "variable species" is usually composite, several races or "elementary species" living in hybrid colonies. I do not know that any such experimental demonstration has been made in the case of animals except upon domesticated or semi-domesticated forms. The facts brought out by a study of the Floridan forms of *Liguus* amount to a demonstration that the variable colonies are composite. They are Mendelian mixtures of races found pure in other colonies. Mendel's law of segregation and the doctrine of unit characters in inheritance give a key to the composition of these hybrid colonies. There remain many points which can be elucidated only by breeding the snails.

My objects in this paper are to give the facts upon which this interpretation of the color-variability of *Liguus* rests. To extend our knowledge of the distribution of *Liguus* in Florida. To show that the present distribution of these snails is directly related to physiographic changes during Pleistocene time and still in progress. Finally to trace the migrations which have resulted in the existing pure and hybrid races of these snails.[1]

For the material used in this study I am chiefly indebted to Mr. Clarence Bloomfield Moore, who personally and through his assistants collected in all parts of the *Liguus* territory except the southwestern group of keys. Mr. Moore applied to the field investigation of the distribution of *Liguus* the critical and thorough methods which characterize his archæological work. The result has been a very great extension of our knowledge of the subject, and the possession of data and specimens unequalled in the collections of all other museums combined. Through the kindness of Mr. Moore, collections were made on the southwestern keys by Mr. J. S. Raybon and by Messrs. Stewardson Brown and Henry W. Fowler. Finally Mr. C. T. Simpson and the writer visited the keys from Key West to Bahia Honda. Various small lots have been received from Messrs. Henry Hemphill, Joseph Willcox, Morgan Hebard and others; and collections in the Miami region have been made by Mr. S. N. Rhoads, Dr. J. W. Harshberger, and the writer. All of these lots have been of value in completing the data on distribution of the several races.

Notes on the occurrence of *Liguus*, particularly relating to its northern limits and to its recent extinction in many localities, compiled from Mr. Moore's field notes, are given in an appendix. Localities carefully investigated where *Liguus* was *not* found are also noted therein, and indicated on the accompanying map, Plate XL, drawn by Dr. M. G. Miller. As much of the evidence is rapidly disappearing, the value of these field notes will be apparent.

II. RELATIONSHIPS OF LIGUUS AND ITS ADVENT IN FLORIDA.

The genus *Liguus*, comprising highly colored tree-snails of Cuba, Haiti and Florida, is a genus of the subfamily *Orthalicinæ*, one of the divisions of the family *Bulimulidæ*. It is generally admitted that this family is of South American origin. Twenty-three of its twenty-eight genera are found in South America; and there the group has undergone extensive adaptive modification.[2] That tropical South America was the radiation-center of *Orthalicinæ* is indicated by the existence there of five of the six known genera, some terrestrial, others arboreal, and

[1] The size, shape and weight of these shells deserve exact investigation. In these characters many colonies of the pure races have become differentiated. Not less important than the coloration would be the comparison of these characters in the various components of the hybrid colonies. I had begun this investigation, but my time, limited by the necessity of turning out a certain quantity of systematic work, would not allow me to carry out my original intention. I have indicated the general character of the colonies, leaving their investigation by the exact methods of biometrics for someone working under less exacting conditions.

[2] The origin and taxonomy of *Bulimulidæ* have been fully discussed in *Manual of Conchology*, XI to XIV.

inhabiting the whole tropical and subtropical region. Also by the absence of fossil forms of the group in any other region. Two genera of *Orthalicinæ* range outside of South America: *Oxystyla*, from southern Brazil to northern Mexico and southern Florida, and *Liguus* in Haiti, Cuba and Florida. The Floridan forms are in part identical with those of Cuba, in part different from any Cuban races, though obviously of the Cuban *Liguus fasciatus* type.

The Floridan land snail fauna associated with *Liguus* is in large part of Cuban origin (Cuban species or groups). None of these Cuban forms have been found in the Pliocene of southern Florida, which contains a varied fauna of land and freshwater mollusks.

The foregoing among other considerations go to show that *Liguus* reached Florida from Cuba, and that it was probably a post-Pliocene immigrant. In what manner its advent was made is not essential to the purposes of this essay; but the transportation of living snails in holes or sealed to the bark of floating trees, or of the eggs by hurricanes, suggest themselves. I have elsewhere given reasons for attributing the Cuban element in the Floridan snail fauna to involuntary passengers whirled up into the air with Cuban forest débris, to be scattered over sea and land along the Florida Strait. That actual land connection between Florida and Cuba existed as late as the life-time of *Liguus* in Florida seems improbable. The southern key region seems the most likely landing point of *Liguus*, both because of its proximity to Cuba and because the present distribution of races is most readily explicable by that hypothesis.

By whatever means *Liguus* reached Florida, the present Floridan forms are not a monophyletic group. They were not all derived from a single introduction, but are due to two or perhaps three importations. (1) *Liguus crenatus* is a widely spread Cuban form, undoubtedly evolved in substantially its present form before introduction into Florida. Reasons are given below for considering it the first form introduced into Florida. (2) *Liguus solidus* of the southwestern keys and *Liguus fasciatus lignumvitæ* of Lignum Vitæ Key possess much of the color-pattern of typical *Liguus fasciatus* of Cuba,[3] though they have been modified enough to be quite distinct from any existing Cuban race. These must be the survivors of another importation of the *L. fasciatus* stock from Cuba.

The *Liguus fasciatus roseatus* and *L. f. castaneozonatus* may have been derived from a third importation from Cuba, but it is at least as likely that these forms evolved from the same *fasciatus* stock which gave rise to *L. f. lignumvitæ*. If so, the latter must have changed much less since the importation. No Cuban forms closely resembling *roseatus* or *castaneozonatus* are known.[4]

[3] Figures of varying forms of the typical race of *Liguus fasciatus* from Cuba may be seen in the *Manual of Conchology*, XII, Plate LVII, figs. 70 to 74; Orbigny's Mollusques de l'ile de Cuba, Plate VI, figs. 1, 2; Reeve's *Conchologia Iconica*, V, *Achatina*, Plate X, figs. 35*a*, *b*, *c*. This typical form does not exist in Florida. In Cuba *Liguus fasciatus* is widely spread, with numerous races and subspecies, the distribution of which is very little known. It is hoped that the record so far as it still exists may be preserved. The ceaseless destruction of Cuban forests for charcoal and clearing the land for cultivation has already destroyed evidence which can never be recovered.

[4] I figured a specimen of *castaneozonatus* said to be from Cuba in *Manual of Conchology*, XII,

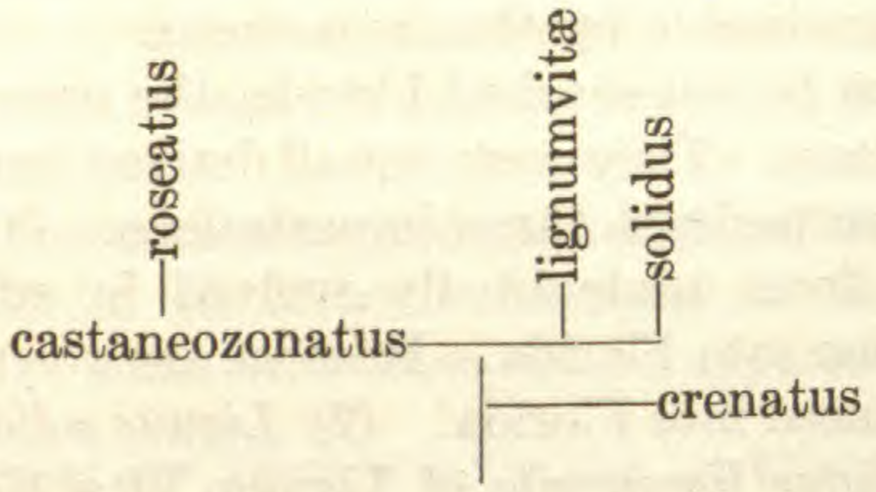
III. PURE AND HYBRID COLONIES OF LIGUUS.

In a general view of large quantities of *Liguus* from several localities it is readily seen that the colonies are of two kinds. Some will be homogeneous, made up of individuals conforming to a single type of color and pattern. Other colonies are heterogeneous, composed of shells readily assortable into two or more groups diverse in color or pattern.

The leading races may be briefly defined as follows:

I. Shell without green or olive spiral lines; solid, porcellanous (Pl. XXXVII, figs. 1–2*a*) ..*L. solidus.*
II. Shell having green or olive lines or their traces (sometimes very faint in melanistic or albinistic forms).
  a. Apex and inner lip more or less rose-tinted.
    b. Shell thin, decorated with numerous brown and purplish spots, streaks and flames (Pl. XXXVII, figs. 4–4*d*).....*L. fasciatus lignumvitæ.*
    bb. Black or chestnut bands or spots forming two zones, one basal, often wanting, the other above, ascending the spire (Pl. XXXIX, figs. 20*g–j*, 22*a–d*, etc.).
L. fasciatus castaneozonatus.
    bbb. No black, chestnut, or purplish markings (Pl. XXXVIII, figs. 11–13, 18–19*a*).
L. fasciatus roseatus.
  aa. Apex and inner lip white; shell white or yellow, with green or olive lines, no rose or brown coloring (Pl. XXXVII, figs. 5–8*b*).....*L. crenatus.*

The relationships and probable phylogeny of the forms may be expressed diagrammatically, thus:



Variation and Mutation in Pure Races.—The pure colonies are so by virtue of their isolation. There can be no reasonable doubt that all of the Floridan races will hybridize if brought together. Different colonies of the pure races often show divergence in size, average shape, solidity, amount of color developed, etc., as described under the several colonies. This seems to be incipient racial differentiation. In some cases it may be a function of the particular local conditions. The reactions of varying conditions upon the individual have not yet been adequately studied, but from the apparent similarity of conditions in the colonies I have visited, it may be doubted whether the racial forms of *L.*

Pl. LVII, fig. 76; but it was a very old museum specimen without locality more exact than "Cuba," collector unknown. It is quite likely that it was a commercial shell localized by guess in the old manner of shell collectors. I have not myself found anything resembling *roseatus* or *castaneozonatus* in Cuba, nor are there any in the collections made there by Mr. J. B. Henderson. It is possible however that *castaneozonatus* may be found there, in which case a third importation into Florida will be demonstrated.

crenatus for example can be directly traceable to the action of physical environment.

Fluctuating variations among individuals of a pure colony are not great. Such conspicuous "mutations" as I have noticed in colonies of pure races belong to the class of varieties produced by loss of a character. Thus in *L. f. lignumvitæ*, Pl. XXXVII, figs. 4, 4*a*, 4*b*, the mutation 4*c*, 4*d* has been formed by loss of the dark color-pattern, the roseate apex and green lines remaining unchanged.[5]

L. solidus has produced similar mutations by loss of some factor controlling the deposition of dark color-pattern. Compare Pl. XXXVII, figs. 1, 1*a* with 1*b*. A few similar cases have been noticed in other pure colonies. While the parentage of these forms is of course unknown, their sporadic occurrence unaccompanied by intergrading individuals in otherwise pure colonies may warrant the inference that we have to do with mutations where by loss of a "color-factor" a considerable change has been effected abruptly. Under natural conditions new forms so produced will result in races only when gametically pure individuals happen to be isolated from the parent race—an unlikely but possible contingency. I do not think that natural selection or sexual selection enter into the question in these snails.

There is evidence that pattern undergoes gradual change in successive generations, beginning with the later whorls, working backward, affecting the early post-embryonic whorls last. Thus in *castaneozonatus* there are colonies in which the dark pattern extends upon the last whorl (Pl. XXXIX, figs. 22*a–d*, 23, 23*a*), others in which it is restricted to the spire (Pl. XXXIX, figs. 20*g–j*). In decadent series the last remnants of the pattern always remain on the early whorls, never on the later (Pl. XXXIX, fig. 20*j*), as if its loss were due to decreasing potency of the factor or factors for brown color as the individual grows older. I do not doubt that new color-races have been produced by this process; and as its action seems to affect a whole colony, the resulting races would have the advantage (in species-forming) of gametic purity, which would not be possessed by similar forms produced by the mutation process. Probably *castaneozonatus* has been converted into *roseatus* in this way. In progressive series the early whorls are the last to be affected by changes initiated on later whorls. Thus in *castaneozonatus* the complete coalescence of brown flames into continuous zones is first manifest on the later whorls (Pl. XXXIX, fig. 22*a*), but only in the most progressive (or as Hyatt terms it, accelerated) colony has this coalescence invaded the early whorls (Pl. XXXIX, figs. 23, 23*a*, Key Largo). Hyatt, Branco, Grabau and others have traced actual phylogenies of cephalopods and gastropods in which the changes proceed in this fashion. Much therefore is to be said in favor of evolution by variation in the potency of the character-determining factors during ontogeny, combined

[5] The mutation 4*c*, 4*d* would technically be *L. f. roseatus* so far as color is concerned, but various peculiarities in the remaining pattern, as well as the shape and light texture of the shells show that we are dealing with a mutation of the *L. f. lignumvitæ*, in a colony of which these were found, no other form of *Liguus* inhabiting the same key.

with Hyatt's idea of acceleration of these variations in phylogeny—a doctrine which palæontology seems to support. The "law of biogenesis" involved in Hyatt's doctrines is much too large a subject for discussion here.

The origin of races by suppression or absence of characters may be made plainer by a simple formula, in which letters stand for the characters, thus:

Presence of green lines, *G*, absence *g*.
Presence of rose coloring, *R*, absence *r*.
Presence of yellow coloring, *Y*, absence *y*.
Presence of brown coloring, *B*, absence *b*.
Sutural and peripheral lines, dark, *L*, white *l*.

The several forms would have formulas as follows:

Liguus fasciatus lignumvitæ,	*GRYBL*, or *GRyBL*.
Liguus fasciatus castaneozonatus,	*GRYBL*, or *gRyBL*.
Liguus fasciatus roseatus,	*GRYbL*, or *GRybL*.
Liguus fasciatus testudineus,	*GRYBl*, or *gryBl*.
Liguus crenatus,	*Grybl*, or *GrYbl*.

Two pairs of characters, yellow or white ground, and thick or thin columella, run through nearly the whole Floridan series, probably as Mendelian alternatives, and not consistently correlated with other features. Although they readily lend themselves to biometric treatment I have not had time to consider them in this paper.

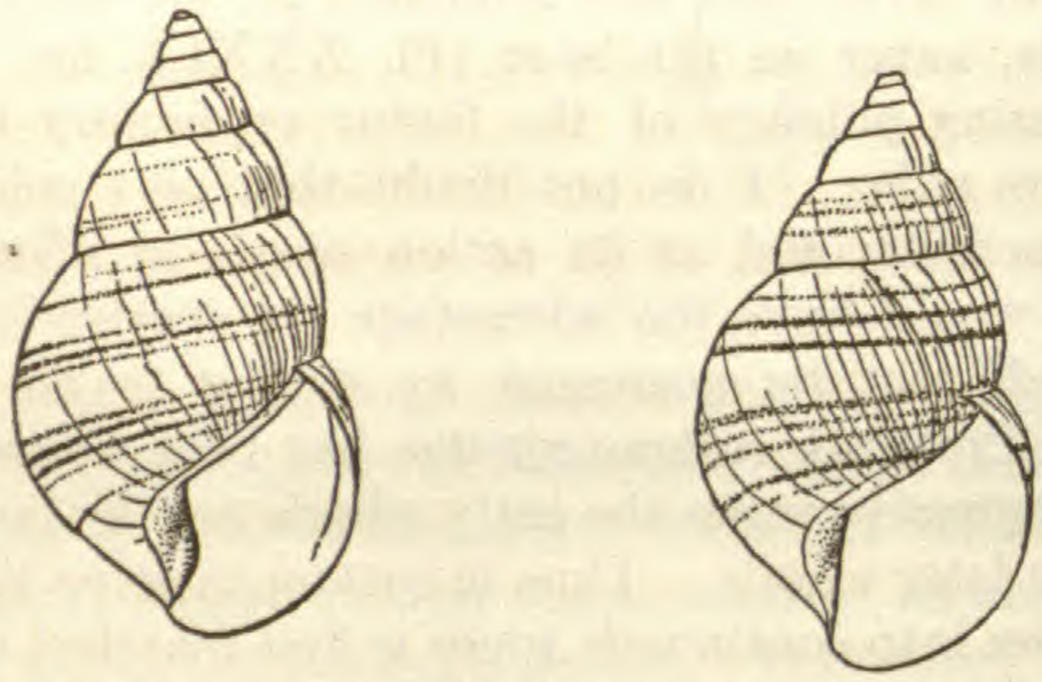


FIG. 1. *L. crenatus* segregate, from the hybrid colony of Key Largo, showing heavy and thin forms of columella.

Variations in intensity or extent of a pattern among individuals of one colony (as in Pl. XXXIX, figs. 22*a*–22*d*) may be due to increase of potency in a character inherited from both parents; but this would not apply to differences in intensity between separate colonies. Here we must recognize that progressive or retrogressive changes in the potency of factors determining color or pattern have taken place. In adjacent colonies, undoubtedly of common parentage,

one may show a strong tendency to restrict a given pattern, another to spread it (*cf.* Pl. XXXIX, figs. 20*g*–20*j*, Miami, and figs. 22*a*–22*d*, Cutler).

Each character acts as a unit in variations of potency. Thus in the keys north of Largo, pink color is unusually strong in several colonies, but yellow is very strong in some, almost absent in others. The green lines also vary independently of yellow or pink. Moreover, the loss of markings of one color does not affect the rest of the pattern.

Hybrid colonies of Liguus are found only in places where the topographic conditions have permitted two or more pure races to mingle in the same woodlands. That the various forms of these colonies actually hybridize is shown by the fact that the eggs laid by one parent produce several color-forms. Of four sets of eggs on the point of hatching examined from the Miami colony, three contained embryos of three patterns, the other of two patterns. One set of nine eggs deposited in the earth under a bell-jar by a snail brought by me from Miami, similar to Pl. XXXIX, fig. 20*k* (*roseatus* pattern), male parent unknown, hatched into 4 *crenatus* pattern, 2 *roseatus* pattern, 2 *castaneozonatus* pattern, 1 egg not broken.[6]

In all hybrid colonies there is almost *complete segregation of the component racial patterns.* The only evidence of blended inheritance seen is in certain very rare individuals, apparently *crenatus* × *roseatus*, from south of Miami, in which the apex is white but the parietal wall shows faint pink coloring. Possibly those *castaneozonatus* in which the chestnut color is reduced to a few pale spots (as in Pl. XXXIX, fig. 20*j*) might be considered as blends, but they admit of another explanation.

The form *castaneozonatus* is nowhere known as a pure race. It is likely that *roseatus* arose from (gradual?) loss of the ability to deposit brown color in some one colony, which later attained a wide distribution; subsequent restoration of communication with the parent stock of *castaneozonatus* resulted in a widespread hybrid race.

Incipient races formed by the appearance of new characters, probably by mutation, are seen in *L. solidus pictus*, *L. fasciatus marmoratus* and *L. f. testudineus*. The dark pattern in these is not a modification of the ordinary pattern, due to diminishing or increasing potency in its ontogeny (as are the various local forms of *L. f. castaneozonatus*, etc.). It is a new pattern. In fig. 2, it will be seen that in the normal patterns such as *castaneozonatus* (fig. 2, *A*) and *lignumvitæ* (fig. 2, *B*) there is a dark border (*s*) immediately below the suture, followed by a white band; at the periphery there is a dark line (*p*) bisecting a white band. In *testudineus* (fig. 2, *C*) the sutural and peripheral lines (*s'*, *p'*) are white, and the positions of the white bands of the other forms are occupied by interrupted dark bands connected with the longitudinal flames. They are *negatives* of the normal patterns. The embryonic and early neanic whorls never have the

[6] These patterns are readily distinguishable in the embryo snails by the presence of clear rose color in *roseatus*, rose color with darker stripes in *castaneozonatus*. I do not know that *crenatus* could be distinguished from *testudineus* at this stage, both being white.

dark pattern of *castaneozonatus*. It appears however that in the case of *testudineus* at least, the new pattern occurs only in a complex hybrid colony, composed of *crenatus* × *roseatus* × *castaneozonatus;* it may have the characters of either

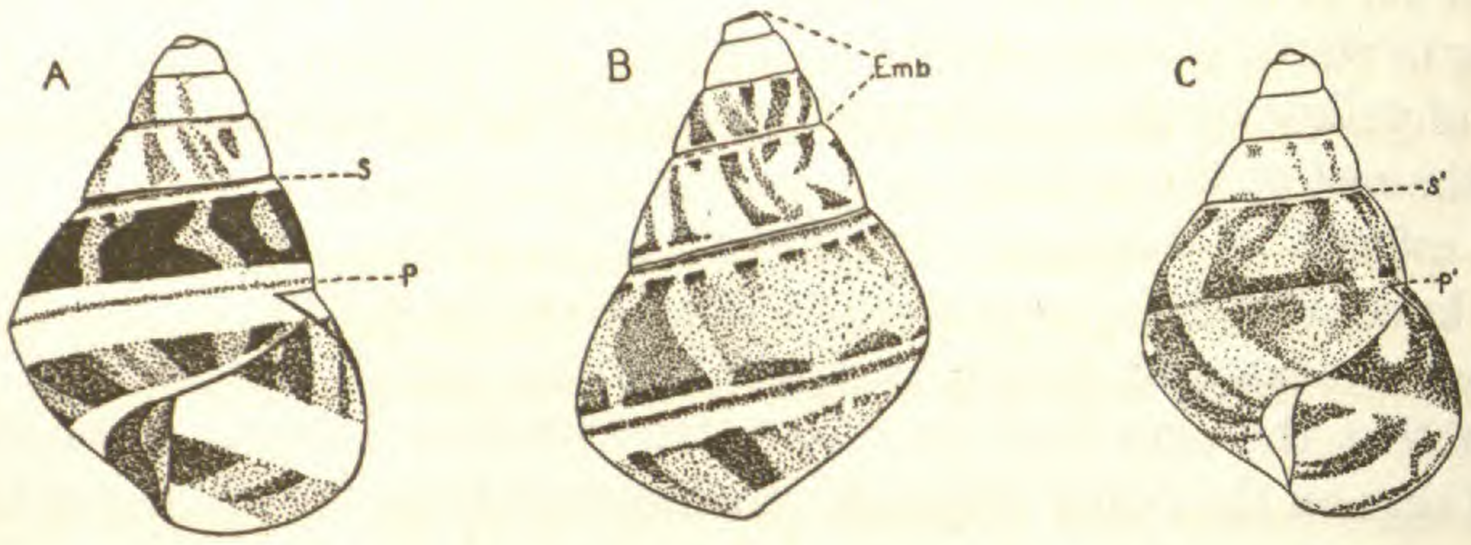


FIG. 2. Young shells of *Liguus fasciatus castaneozonatus, A; L. f. lignumvitæ, B;* and *L. f. testudineus, C,* × 2. *Emb.*, embryonic whorls of the shell. *s, s'* sutural band; *p, p'* peripheral band.

roseatus or *crenatus* in its embryonic and early neanic stages. The inheritance factor for pattern may therefore be linked in some way with hybrid parentage, rather than a pure de Vriesian mutation.

In the case of *marmoratus* (Pl. XXXVII, figs. 9, 9*a*) on Key Vaca the new pattern is apparently becoming of racial significance, although the race is still hybrid.

No *crenatus* × *roseatus* hybrid is known, apart from the colonies also containing *castaneozonatus.*

IV. COLORS AND PATTERNS OF LIGUUS.

The colors of *Liguus fasciatus* are in both the cuticle and the prismatic layer of the shell. The cuticle is very thin and pellucid, except where colored green. It is largely lost from the spire in adult shells.

The green lines are wholly cuticular and may be readily scraped off with a knife. They are often lost except immediately back of the lip in adult shells, by abrasion or weathering and loss of the cuticle. Though the color is only "skin deep" these lines are wonderfully persistent, being present in most individuals of all varieties of *L. fasciatus* and *crenatus*. Even in melanistic varieties they may be traced as lines of blacker hue or different degree of reflection. By acceleration they have extended back upon the last embryonic whorl, where they are discernible as shallow grooves. The lines are usually marked in the calcareous layer below the cuticle by retarded deposition, indicated by sinuation of the growth-lines, and a notch in the lip-edge at the termination of each green line.

The yellow pigment of xanthistic forms is below the cuticle. In the growing shell it is always strongest close to the outer lip, on the part of the shell last formed. *As growth proceeds, this color fades*, so that it becomes fainter the farther it recedes from the end of the last whorl. In most xanthistic races, adult or nearly adult individuals which have undergone a long resting stage have lost

most or all of the yellow color, but with renewed growth the yellow appears along the growing edge, as shown in Pl. XXXVIII, fig. 18, etc. Young shells of xanthistic races are therefore more strongly colored than the corresponding whorls of any of the adult shells of the same colonies. This fading of the yellow pigment in living shells is the more remarkable because in dry museum specimens collected over twenty years ago, the yellow still remains. In Say's type of *Liguus solidus* the yellow tint may still be seen, although it was collected in 1824. Yellow is a new feature in Floridan *Liguus*. There is rarely any trace of it in Cuban forms. Yellow and white grounds are probably a pair of Mendelian characters in Floridan *Liguus*. In inheritance yellow is evidently independent of the rest of the color-pattern.

The chestnut-brown and blackish pigment is in the prismatic layer of the shell, and is the most permanent, traceable in dead, weathered shells after other colors are lost. Brown intensified becomes almost black; overlaid with a film of the white ground-color it becomes purplish or bluish. It is never interchangeable with yellow, in *Liguus*, however the case may stand in vertebrates. This is obvious in most of the colonies. Thus at Key Vaca (Pl. XXXVII, figs. 9–9*d*) the brown pattern varies independently of yellow, which may be intense, weak or absent in forms with maximum or minimum brown pattern or none at all. While the chestnut zones overlay yellow zones in most cases, yet in *Liguus* the darker color cannot be considered to be merely a further stage of oxidation of the yellow pigment. The two are absolutely distinct in inheritance and phylogeny. The *patterns* of black or brown never appear in yellow. Whether the inheritance factor for *dark color* is or is not separable from that for *flame pattern* under one guise or another, it is certain that it is never dissociated from it in *Liguus* and related genera, and equally certain that yellow never is controlled by that pattern.

Rose or pink coloring of the early whorls, associated with rose, pink or purple on the parietal wall and columella, are highly characteristic of *Liguus fasciatus* and seem absolutely constant in pure races of that species and its derivative varieties. Rose is apparently dominant in hybrids.

The primitive color-pattern of *Liguus* must have consisted of brown longitudinal stripes or flames on a white ground. This conclusion rests upon the fact that this pattern characterizes most of the species of all the genera of the sub-family *Orthalicinæ* to which *Liguus* belongs, at least in their young stages. It is highly improbable that the same fundamental pattern would have been independently acquired by species of a half dozen related genera,[7] but far more likely that they inherited it from a common ancestral stock. If this be so, then the spiral band patterns are secondary. This does not apply to the green lines, which have no connection with the flame pattern.

The dark flames usually appear on the last embryonic whorl as continuous

[7] *Manual of Conchology*, XII, plates XVI to LX. Similar flame or streak patterns are common in other sub-families of *Bulimulidæ*.

stripes or as spots (fig. 2*b*, *emb.*, p. 436). On the neanic whorls they may either become interrupted, leaving only spots at the ends (fig. 2*b*), or they may spread and coalesce laterally producing a pattern of spiral zones or bands. At the periphery the flame pattern is interrupted by a spiral white band, usually bisected by a spiral dark line. There is also a white band below the suture, and in races with normal coloration there is a narrow darker line immediately bordering the suture below.

The various races of *Liguus* can mostly be distinguished in the embryonic shells, and the color pattern is characteristically expressed in the early neanic whorls.

Certain forms seem to be new mutations in the de Vriesian sense. Such are the form *solidulus* of *L. solidus* in which the positions of the yellow and white bands are reversed as in a photographic negative. The forms called *pictus*, *testudineus* and *marmoratus*, though independent mutations, are similar in having dark color on areas which should be white in normal patterns. All of these occur in hybrid colonies, and their real gametic constitution probably can only be determined by breeding under control. I have seen no similar forms from Cuba.

V. DISTRIBUTION AND MIGRATIONS OF LIGUUS.

Liguus is restricted on the mainland of Florida to places on a narrow peripheral strip of firm land, sometimes perhaps six miles wide, frequently much less. Inland this strip is bounded by the everglades in the eastern and southern parts of the peninsula. In the west it is doubtful whether *Liguus* occurs at the present time on mainland north of Cape Sable. All known localities are insular.[8] Parallel to this mainland strip in the east and south runs the line of keys, also inhabited by *Liguus*, but at present isolated from the shore strip.

On account of the rather extensive though superficial submergence of Florida during the Pliocene and the absence of *Liguus* from known Pliocene deposits, it is not likely that these snails existed there before the close of the Pliocene, and it seems more likely on geological grounds that their advent was in Pleistocene time. Agassiz and others have pointed out that there has been elevation during the Pleistocene, shown by raised reefs, amounting to over six feet in some places. It is quite likely however that the land area in the peripheral region was as great or greater at the period of depression as it is now, since the subsequent degradation must have been much greater on the unconsolidated older area than on the newly raised reefs.[9] At all events, it is obvious that the destructive agencies

[8] "We know of high land inland on the West Coast but we did not search it. People are living on the mainland in from Chokoloskee Key" (C. B. Moore).

[9] According to T. W. Vaughan, Pliocene deposition in Florida was closed by an elevation, and was followed by a Pleistocene submergence. Pleistocene time was closed by an uplift, after which the Everglades were formed (*Science*, July, 1910, pp. 25, 26). If the Pleistocene submergence was as extensive as one would gather from Dr. Vaughan's brief account, then the land fauna of the keys and adjacant mainland must be wholly post-Pleistocene, or Holocene. This does not appear probable; and Dr. Vaughan does not expressly state that all of the southern region was submerged.

now predominate over those making land whether by elevation or otherwise. On the lower keys which I have explored, all stages in the process of disintegration are readily observable—flask-shaped "cisterns" of fresh water in the consolidated rock, sinks produced by their caving in, finally channels from caving of the subterranean water courses, etc.[10] Professor Alexander Agassiz,[10] who examined the eastern keys, writes: "It is most probable that Key Biscayne Bay, Card's Sound, Barnes Sound and the smaller sounds to the north of Key Largo, as well as a number of ill-defined sounds between Barnes Sound and the Bay of Florida, owe their origin to the erosive and solvent action of the sea. A glance at the chart clearly indicates the former connection with the mainland of the line of keys extending from Key Biscayne to Long Key." The tongues of land connecting Key Largo with the mainland, the Rubicon and Arsenicker Keys, and the shoals inwards from the Ragged Keys are mentioned by Agassiz as remnants of the former land. The "sounds may have originally been sinks [formed by the action of rain water] similar to those of the Bermudas and Bahamas, and have, like those of these islands, been changed into sounds by the breaking through of the barriers separating them from the open sea. This would allow the formation of more or less deep channels . . . through which material held in suspension or solution could pass out."

We have to do therefore with a region which has undergone considerable changes in post-Pliocene time, ending with a period of dissolution still in progress, during which the keys have become progressively more fully isolated from the mainland and from one another. This progressive disintegration of the land areas, which seems established beyond question, enables us to fix the relative dates of the successive migrations of *Liguus* with a high degree of probability.

1. *Liguus crenatus* (Pl. XXXVII, figs. 5–8*b*) occurs as a pure race only in the most isolated localities (fig. 4, page 442). At Lossman's Key on the western border of the Ten Thousand Islands. On New River (fig. 3, 4) where it is isolated by a long stretch of pine and palmetto land. On Elliott's Key, isolated by the deep Cæsar's Creek, and on the keys south of Largo. A glance at the map (Pl. XL, and fig. 3, page 441) will show that these are peripheral areas, which must have been among the first to be isolated. It appears therefore that *L. crenatus* is an older race in its region than the more highly colored races, which, coming later, found the paths to the peripheral keys barred by channels. Probably *crenatus* overran the area made available by the elevation of the reefs, as soon after that event as suitable woodlands became established. The land surface in southern Florida must then have been far greater than at present. The subsequent isolation of the scattered colonies of pure *L. crenatus* has permitted the formation of local races, as noted in the descriptions of the colonies. On the mainland, where later migration was unrestricted, the *crenatus* territory has been invaded by other races, forming hybrid colonies.

[9] For observations on the formation of sinks and lakes by solution, with estimates of material removed, see E. H. Sellards, *Third Annual Rep. Florida State Geol. Survey*, p. 50. Also see A. Agassiz, The Florida Elevated Reef, *Bull. Mus. Comp. Zool.*, XXVIII, No. 2, 1896.

2. *Liguus fasciatus roseatus* (Pl. XXXVIII, figs. 11–13, 18–19*a*) as a pure race occupies keys between those of pure *crenatus* and those of the hybrid forms in the east (fig. 3) and in western Florida it ranges north of the hybrid form (fig. 5, page 442). It occurs only on keys which from their positions must have remained connected with the mainland after the separation of those occupied by *L. crenatus*. These keys must in their turn have been isolated in the gradual disintegration of the land prior to the isolation of those occupied by the chestnut-zoned race.[11] This is so obvious, both in several colonies in the west and in the area occupied by seven colonies north of Key Largo, that we cannot escape the conclusion that *roseatus* migrated into its present localities after the migration of *crenatus* and before that of *castaneozonatus*. That the position of the colonies of *roseatus* relative to the other forms is fortuitous seems so improbable as to be negligible.

In *roseatus*, as in *crenatus*, there has been conspicuous local differentiation. In view of the prevalence of similar forms over far greater areas where the colonies are not isolated, it can hardly be doubted that isolation has been instrumental in the evolution of these incipient races. As noted in the descriptions of the colonies, they are characterized by varying degrees of intensification of the several factors involved in the *roseatus* organization, and not by new characters.

3. The hybrid colonies occupy areas more central than the pure races of *crenatus* and *roseatus*, or than *L. solidus*. On the west coast, at Chokoloskee and Rabbit Key, the hybrid segregates into *roseatus* (Pl. XXXVIII, figs. 14, 14*a*, 14*b*) and *castaneozonatus* (Pl. XXXVIII, figs. 14*c*, 14*d*, 14*e*). Apparently *crenatus* did not penetrate so far north on this coast. The pure colonies of *roseatus* lie farther north.

In the south and east, Middle Cape Sable, Grassy and Vaca Keys, the mainland bordering Biscayne Bay and Key Largo (see fig. 6, page 442, and fig. 3, page 441), the hybrid race segregates into *crenatus*, *roseatus* and *castaneozonatus*. The isolation of these hybrid colonies from one another is conspicuously less wide than in the case of the pure races, though the rapid disintegration of the periphery of the peninsula has already brought about some separation. Key Largo apparently formed a peninsula of the mainland up to a very recent period. The Arch Creek colony is now separated from those south of Miami. There is probably almost or quite continuous hammock from Miami to Detroit. How far this great colony or series of colonies extends in the direction of Cape Sable is unknown.[13] The colonies on Grassy and Vaca Keys are the most isolated, but great shoals lie in the interval, and it seems reasonable to suppose that an extensive tract of land formerly connected these south-central keys with the mainland, since the *castaneozonatus* and *roseatus* elements of their *Liguus* fauna cannot be derived from the keys either east or west. In this connection it may

[11] A single colony of *roseatus*, that at South Cape Sable, is in an area where we would expect a hybrid race. It is not unlikely that local conditions if known would indicate an early isolation of this colony.

[13] I understand that south of Detroit the everglade prevails. There is also everglade between Detroit and the east coast I am told.

be mentioned that *Oxystyla floridensis* of the southern keys also occurs at Cape Sable and extends up the west coast to Pavilion Key.

FIG. 3. Southeastern coast of Florida from Lower Matecumbe Key to New River, showing the distribution of pure races of *L. crenatus* (first incursion, horizontal lines), *L. f. roseatus* (second incursion, black), and of the hybrid race formed with *L. f. castaneozonatus*, which overrun part of the area believed to have been previously occupied by the two pure races (third incursion, cross hatched). Hypothetical former extension of hybrid race indicated by dotted lines.[12]

[12] Whether *Liguus* occurs on the mainland near Key Largo is unknown, as no data are available on the region indicated by queries (?) on the map. Although Key Largo is now separated from the mainland, it appears that the isolation is quite recent. As late as 1823 Largo is said to have been a peninsula. The inside passage required a "portage of six boat-lengths." "Key Largo formerly abounded with mastic, lignumvitæ and mahogany, but the most valuable has been long cut down, and there is none now but very young timber." Charles Vignoles, *Observations upon the Floridas*, New York, 1823.

The peculiar mutations *testudineus* and *marmoratus* occur in hybrid colonies.

4. *Liguus solidus* in its several forms (Pl. XXXVII, figs. 1, 1*a*, 2, 2*a*) is confined to the southwestern keys, where no other *Liguus* occurs (see fig. 7).

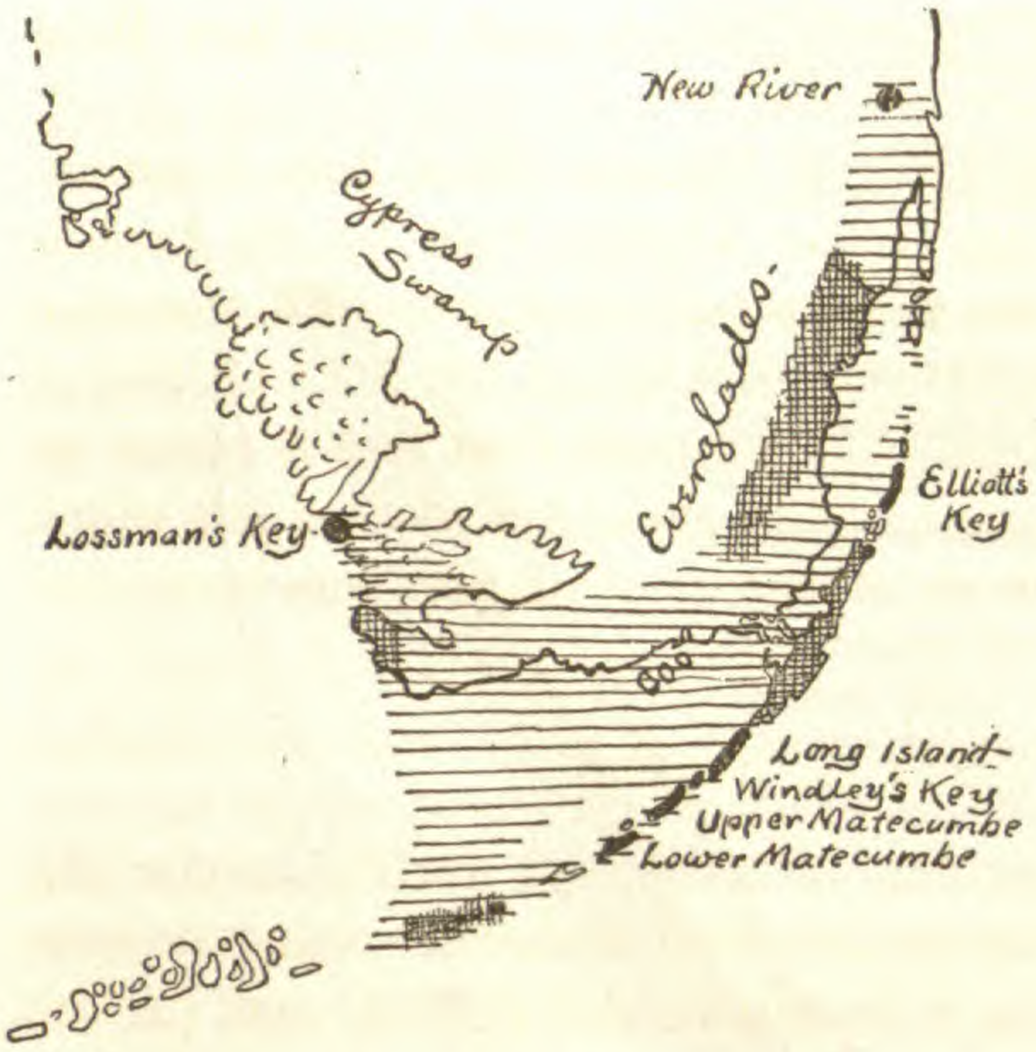


FIG. 4. Distribution of *Liguus crenatus*.

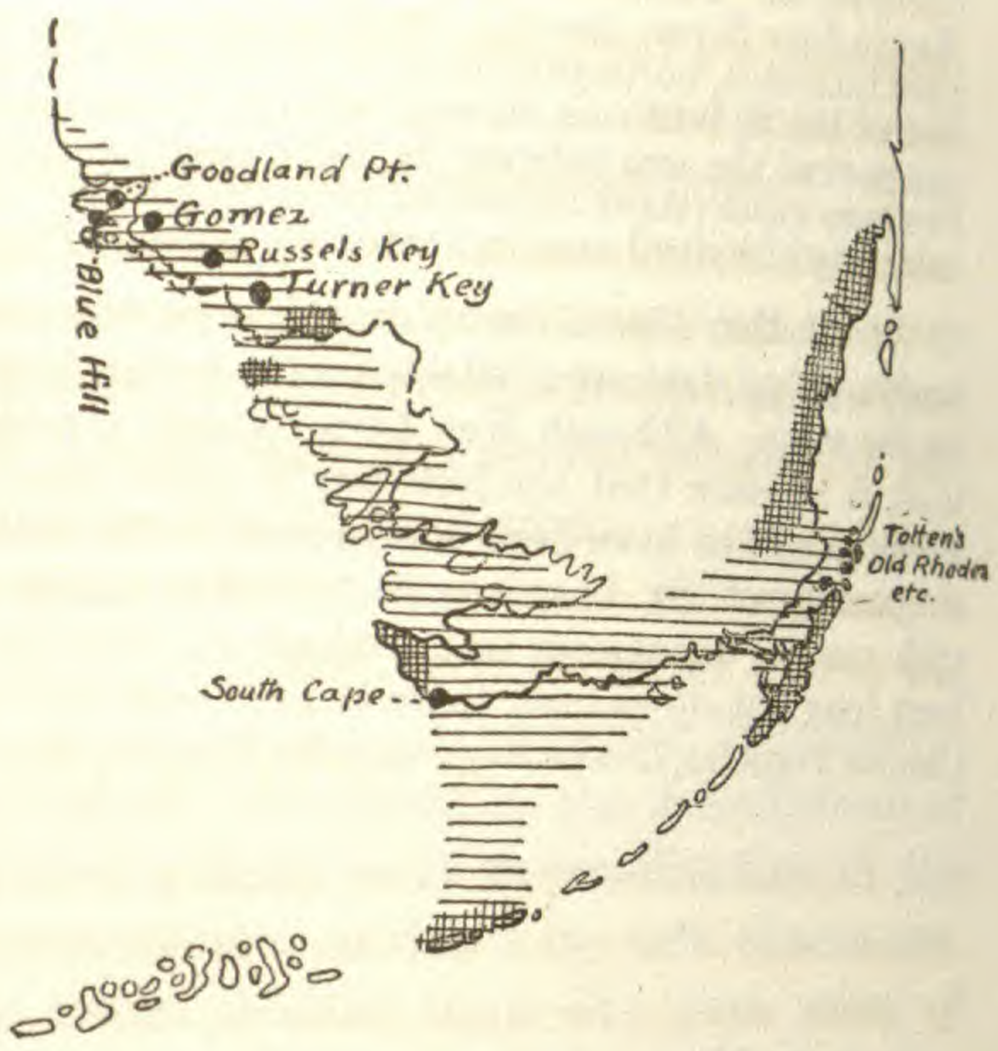


FIG. 5. Distribution of *Liguus fasciatus roseatus*.

Pure colonies black. Hybrid colonies cross hatched. Probable former distribution in horizontal lines.

FIG. 6. Distribution of *Liguus f. roseatus* × *castaneozonatus* (*); AND OF *Liguus crenatus* × *roseatus* × *castaneozonatus* hybrids. Known colonies in black, probable former range in horizontal lines.

FIG. 7. Distribution of *Liguus solidus*. Known colonies in black.

Its advent was probably after this group of keys had been isolated from the other keys and the mainland, but before the area had been broken into many separate keys as at present. The presence of identical forms points to former continuity of the land from Little Pine and No-Name Keys to Key West. *Oxystyla undata reses* has the same range but extends farther east, from Key West to Grassy Key.

5. *Liguus fasciatus lignumvitæ*, the sole race on Lignum Vitæ Key, is anomalous in distribution. It is closer than any other Florida race to the typical form of the Cuban *L. fasciatus* in coloration, though still distinctly differentiated otherwise from the parent stock; and it is certainly not at all related to forms of the keys adjacent to Lignum Vitæ. We can only suppose that this is either an independent migrant from Cuba or a remnant of the same *fasciatus* stock which became modified into *L. solidus* farther west, which by isolation has been preserved on Lignum Vitæ Key.

VI. STATION AND HABITS OF LIGUUS.

Liguus lives upon the trunks and branches of trees and shrubs, preferring dense shady woods, neither sandy nor swampy but well drained. It never lives in pine woods or mangrove thickets, always in hardwood groves, and prefers rather smooth-barked trees such as the gumbo-limbo (*Ursera simaruba*). Such woods in Florida form what are known as hammocks.[14] As the hammock land is dark, rich soil, it is much in demand for cultivation in a country otherwise made up of sand and swamp. The habitat of *Liguus* is therefore year by year diminished; the gaily clad snails near their nemesis; and before many years they will become extinct except in some remote spots too inconsiderable for cultivation. Throughout its range in Florida, *Liguus* lives under very similar conditions. The climatic conditions are certainly not much varied; all of the colonies are at practically the same slight elevation above the sea. To casual observation there seems to be far more difference between the more open and denser parts of the woods inhabited by one colony than there is between corresponding parts of other colonies.

The eggs are elliptical, with a thin, pale brown, minutely granular, calcareous shell, and measure 5.2 × 7.2 to 6 × 8 mm. They are laid in groups of eight or ten, buried in the ground or under leaves and trash. Eggs taken at Miami, January 26, were hatching. An individual in confinement laid eggs in July.

Liguus is active in rainy or damp weather and I think chiefly by night. In daytime I have usually found them quiescent. During dry seasons they seal themselves firmly to the bark, preferably in crotches, knot-holes or other protected places. Since these snails lay their eggs in the ground, and ascend the highest trees, their powers of travel are considerable. *Oxystyla* has the same habits as *Liguus*. The food of these snails is chiefly if not entirely the minute

[14] Not "hummocks" as written by some persons. Hammock is a local and native term, in universal use in Florida, and also used by writers on the region as long ago as the latter half of the 18th century. To associate it with hummock (*cf. Century Dictionary*, page 2917) is an error.

fungi growing on bark, so far as I can judge from the contents of their stomachs. Those kept in captivity would not eat lettuce, dandelion, apple or other green fodder provided.

FIG. 8.

Liguus is frequently broken as the result of falling, and many specimens extensively repaired are found. One from near Planter, Key Largo, which had broken the spire and lost several pieces of the shell is drawn in fig. 8.

VII. DESCRIPTIONS OF THE COLONIES OF LIGUUS.

1. PURE COLONIES OF LIGUUS CRENATUS.

Liguus crenatus (Swains.) was originally collected in Cuba by a brother of the noted naturalist William Swainson. It is found in the northern part of Havana Province, from near Havana eastward.[15] In Cuban *crenatus* the green lines are narrow and usually about equally distributed on the upper and lower parts of the last whorl. The ground is white throughout, never yellow on the last whorl; and the columella is thin and simple, not truncate below in adults; the shell is thin and light; whorls 7 to 7½. The name was taken from the circumstance that there is a slight notch in the lip-edge at the termination of each green line. A copy of Swainson's original figure has been given in the *Manual of Conchology*, XII, Pl. LVIII, fig. 80, and a typical Cuban specimen is shown in Pl. LVIII, fig. 81.

No specimens exactly resembling Cuban *crenatus* have been found in Florida, although in some the deviation is very slight. The presence of yellow coloring is a distinctively Floridan trait.

L. crenatus has usually been considered a variety of *fasciatus* on account of its association with *fasciatus* forms in the hybrid colonies of the east coast. It seems however, both in Cuba and Florida, to be otherwise so distinct a stock that it may well be treated as a "species." It is a more evolved race than *fasciatus*, having lost all brown or other longitudinal (axial) color-marking, and especially by the loss of pink coloring, which is a remarkably constant—in fact invariable—character of *L. fasciatus* and of its Cuban allies *L. blainianus* and

[15] The entire range of *L. crenatus* in Cuba is not known, but specimens from near Havana, Cardenas and Sancti Spiritus are before me. At Matanzas I found typical *L. fasciatus* but no *crenatus*.

L. poeyanus. The presence of rose (varying to pink or purple) on the parietal wall and apex is evidently a very old character in *Liguus*.

The pure colonies of *L. crenatus* in Florida show a great deal of local differentiation. I have thought it well to apply names to the chief races. The variation in length is roughly shown in the following table of measurements of specimens apparently adult, though some of the smaller ones of each lot may be immature.

Length in Mm.	Fort Lauderdale.	Elliott's Key.	Upper Matecumbe.	Windly's I.	Lower Matecumbe.	Lossman's Key (1).	Lossman's Key (2).
59					1		
58					1		
57				1	2		
56				2	1		
55				2	1		1
54					3		1
53				2	3		
52					3	1	1
51	1				6		2
50	1			1	3		4
49					5		2
48					3		2
47				1	6		7
46					2	1	5
45	2				1	2	11
44	1				2	5	3
43	1				1	6	4
42	1				1	12	8
41	2				2	17	8
40	3					10	3
39		1	1			3	
38		2	1			1	1
37		2	1			7	
36		6					
35		7					
34		9	1				
33		7					
32		6					
31		5					
30		5	5				
29		1					
28		2					

Lower Matecumbe Key (text-figure 11 and Pl. XXXVII, fig. 7*a*); *Windly's Island* (Pl. XXXVII, fig. 7). This race rather closely imitates the Cuban *crenatus*, but is differentiated in the following respects: the apex is larger. The green bands are chiefly basal, as a general rule. The spire is longer. There is no colored or tinted sutural margin. Whorls 7½ to 8.

In the series of fifty odd shells from Lower Matecumbe, the cuticle may be slightly green-tinged on the last whorl, but there is no yellow. In about half of the specimens seen the green lines are faint, yellowish olive, or sometimes wholly lacking, as in fig. 7*a*. The shell and columella are always thin.

In a series of fifteen from Windly's Island, all are distinctly marked with green lines. This race may be called *L. crenatus subcrenatus*. Length 58, diameter 26, aperture 24.5 mm. (fig. 11).

Upper Matecumbe Key (Pl. XXXVII, figs. 5, 5*a*). A series of 12 living examples taken by Mr. Moore in 1904, at the western end of the key. They are small, short and wide, with the mouth relatively large, more than half the shell's length; very thin. White, more or less *yellow tinted at the last whorl*, the yellow tint *continuous over the periphery*, intensified around *a small white columellar area;* and there is *a narrow golden sutural margin*. Green lines are present, arranged as in *subcrenatus*. Whorls nearly 6½ in the largest specimens, the last

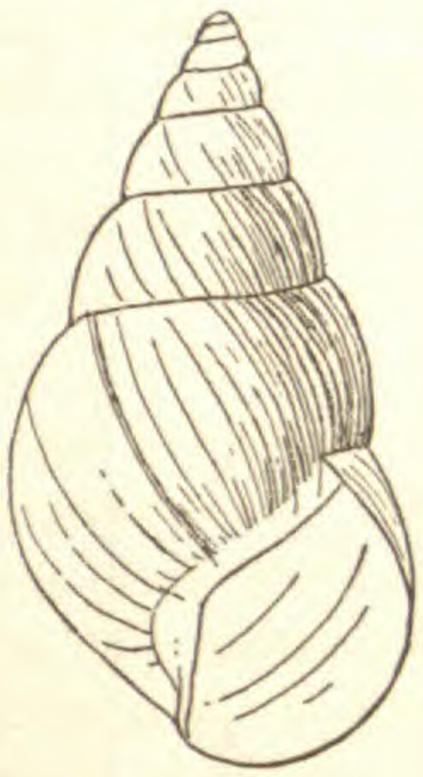


FIG. 9. *L. crenatus* var., Long Island.

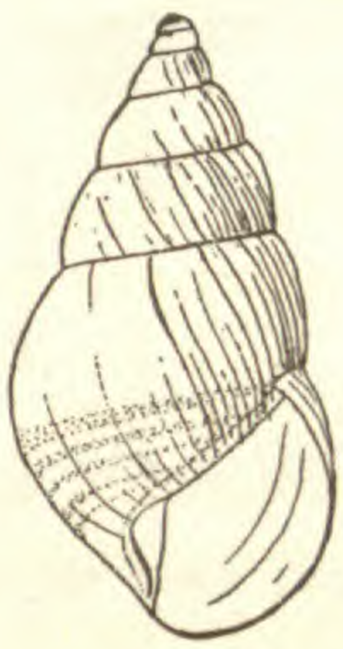


FIG. 10. *L. crenatus* var., Angelfish Key.

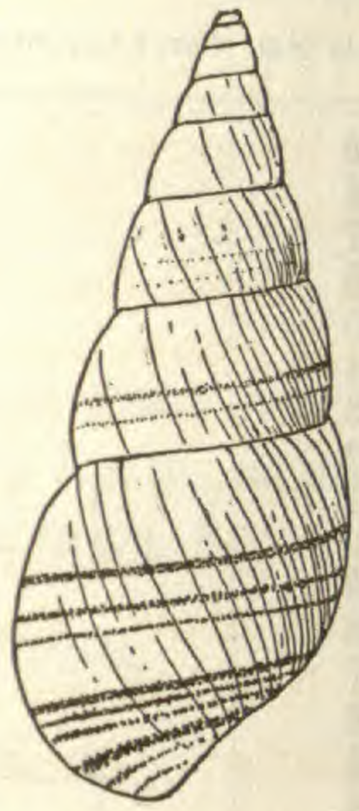


FIG. 11. *L. crenatus subcrenatus*, type. Lower Matecumbe Key.

obtusely subangular at the periphery. The columella is very thin, and the parietal wall usually has a watery, translucent tenuity in large specimens. Length 39, diam. 22.5, aperture 21 mm.; 6¼ whorls. While very like the Elliott Key race, it differs by the distinct green lines and distribution of yellow. I call this race *L. c. matecumbensis*. It is well differentiated from *subcrenatus* by its small size, wide shape and development of a yellow pattern. It lies between the two keys inhabited by *subcrenatus*.

Long Island (Plantation Key) at the west end (text-figure 9). A single living *Liguus* was taken by Mr. Moore in 1904. It is quite *solid*, pure white throughout save for faint traces of grayish lines, evidently the vestiges of green bands. The columella, while thick, is of the simple, non-truncate type. Whorls 7½. Length 52.5, diam. 27, length aperture 25 mm.

The single specimen is quite unlike any other race I have seen, but it is impossible without more material to say whether or not it is a fair representative of its race.

Angel-fish Key (north of the north end of Key Largo) (text-figure 10). Shell moderately solid, rather thin, porcelain-white, very smooth. Close examination shows that there are very faintly traced yellowish-brown lines on the base, so pale as to be readily overlooked. The columella is thin or slightly thickened, not truncate. The spire is contracted near the summit. Whorls nearly 7.

Length 42, diam. 21, aperture 20 mm.
Length 44.5, diam. 22, aperture 21 mm.

Larger specimens were found on the ground, long dead. One measures, length 71, length aperture 31 mm., whorls 8½. It shows no trace of color-pattern, and apparently was like the living form except in size.

This race differs from *elliottensis* by the larger size, greater solidity and glossy, porcelain-like surface. Very few specimens were taken by Mr. Moore, and further collection on the Key is desirable. It may possibly be merely a *crenatus* segregate from a hybrid race. The proximity of Angelfish Key to Largo renders this probable.

Elliott's Key (Pl. XXXVII, figs. 3, 3*a*, 3*b*). Near the south end of the Key a small, fragile race was found by Mr. Moore in 1904. The shells are light, *white with translucent-gray streaks*, sometimes faintly tinted with creamy-olive on the last part of the last whorl. There is *a very faint yellow sutural line* and usually some light yellowish-olive-green lines, chiefly basal, and sometimes wanting. The half-grown young occasionally show two *very faint* wide yellow zones, one above, the other below the periphery. In older shells the upper of these bands shows on the penultimate whorl. 18.5 per cent of the specimens are so marked. The spire is straightly conic, whorls but slightly convex. Columella thin and simple. Apex and columella invariably white. The aperture is about half (47 to 53 per cent) the length of the shell.

Length 39.5, diam. 21, aperture 19 mm.
Length 37, diam. 21, aperture 19 mm.
Length 35.5, diam. 20, aperture 17.5 mm.

This small race, of which I have seen 65 specimens, is very uniform in characters. The shells are fragile, and frequently broken by falling. More than 10 per cent of the adults seen have had holes broken in the shells, usually in the spire, sometimes very large and requiring extensive repairs. The first two whorls are vacated and partitioned off, but generally are not deciduous. This race may be called *Liguus crenatus elliottensis.*

New River, below Fort Lauderdale, 25 miles north of Miami (Pl. XXXVII, figs. 6, 6*a*). Collected by Mr. Moore in 1904. The shell is wide and conic, the last whorl subangular in front; the aperture is half the length, the diameter decidedly more than half. The smooth, glossy surface is often faintly malleated obliquely. It is pure white without a trace of yellow, and has a few distinct lines, varying from bright green to brownish-olive. The lines above and below the periphery are usually widest, and there are often no others on the upper surface. The number of lines varies from one to seven in the specimens seen. Whorls 7. Columella a little thicker than in most forms of *crenatus*, but not in the least truncate. The parietal wall shows translucent-grayish vortex-streaks. This local race may be called *L. crenatus septentrionalis.* Length 51, diam. 28,

aperture 26 mm.; 7 whorls. This is the northernmost point on the east coast where *Liguus* was found by Mr. Moore. The race is apparently a pure one, with no admixture of blood from the Miami race. It shows no diminution of vigor, as might be expected at the extreme northern range of the species. On the contrary, the individuals are large, symmetrical and finely developed. They are unlike any other *crenatus* colony seen.

Lossman's Key, Monroe Co., on the western border of the Ten Thousand Islands (Pl. XXXVII, figs. 8, 8*a*, 8*b*). This is the only *crenatus* form yet found on the west coast. It is usually much more solid than eastern *crenatus*, about 9 shells weighing one ounce. There is a callous ledge within the lip and the columella is almost always wide, solid and obliquely truncate at the base. The apex is smaller than in eastern forms of *crenatus*. It is perfect in 90 per cent of the specimens examined, the others having lost the tip only. Whorls 7; *the last two are usually very convex* above the periphery. The aperture is from 46 to 51 per cent of the total length. The white color of the spire may continue on the last whorl or give place to an increasingly deep yellow, paler at the periphery, and separated from the suture by a narrow white band. There are several greenish lines above the periphery, and a group of yellowish-olive ones on the base. These lines are short, rarely exceeding 1½ whorls long.

Variation is chiefly in the extent and intensity of the yellow, and in the shape of the columella; a few of the thinnest and palest shells having a thin, straight columella (fig. 8) as in typical *crenatus*.

Length 55, diam. 30, aperture 27 mm. (largest).
Length 44, diam. 25, aperture 22½ mm.

The shells were collected in 1904 and 1906, chiefly from a hammock about three miles below the upper end of the Key, and about half a mile inland (first column of measurements on p. 445). Also found in a hammock, reached by ascending a creek near the north end of the key (second column of measurements on p. 445). In the central part of the key (a few dead specimens), and at Mr. Hamilton's place, northwest end of the key about 1½ miles inland. Over 200 shells were taken at the several localities. This race may be called *L. crenatus lossmanicus*.

Liguus crenatus, for some reason at present unexplained, on the west coast apparently never extended north of Lossman's Key. The hybrid colonies further northward, at Chokoloskee and Rabbit Key, segregate into *roseatus* and *castaneozonatus* only, whereas in the area south and east, *crenatus* enters into the combination.

2. Pure Colonies of Liguus fasciatus roseatus from the West Coast of Florida.

The colonies of *roseatus* are plotted on the map, fig. 5, page 442.

Marco Island, Lee Co., on Mr. Pettit's place, Goodland Point (Pl. XXXVIII, figs. 11, 11*a*, 11*b*). The shell is moderately solid but not heavy, not very glossy.

The ground-color is white, faintly pink tinted. *The early whorls, columella, a small part of the base adjacent, and the parietal callus are invariably rose colored. There is a line of pale brown or pink below the suture, and a yellow or pink band at the periphery* (usually not well developed before the ephebic stage in Goodland Point shells, and sometimes delayed until the gerontic). As the pink of the early whorls fades out, on the fourth or fifth whorl it is replaced by a wide spiral band, pinkish at first, but changing to yellow, and separated from the sutures by narrower white bands. In some shells the yellow bands are excessively faint. On the last whorl another similar yellow band on the base becomes visible. The last whorl, or its last half, usually shows few or numerous yellowish-olive or greenish lines, one group above the periphery, another on the base. The columella is usually slender, convex or straight, and continuous with the basal lip below, but sometimes it is strongly truncate. The first embryonic whorl is generally lost in adult shells.

The italics above denote characters common to this subspecies wherever found. The yellow bands and greenish lines are inconstant. Greenish lines are only weakly developed in West Florida *roseatus*, and are often lost by fading and loss of the cuticle in living shells. The mutilated apex is a feature of some colonies only.

Length 52 mm.; diam. 27 mm.; length of aperture 24 mm.
Length 50 mm.; diam. 25 mm.; length of aperture 23 mm.
Length 56 mm.; diam. 28 mm.; length of aperture 25 mm.

108 specimens examined from Goodland Point. Specimens precisely similar to those taken by Mr. Moore in 1906 were collected by Henry Hemphill at Goodland Point in 1883. The same form was found, a few dead shells only, on the Georgia Fruit Company's land. Also living, at Caximbas, Key Marco, 1906 (where the largest of 49 collected is 60 mm. long).

Horr's Island, near Key Marco, at Blue Hill, a hammock tract. The shells are somewhat heavier and attained larger size, adults 53 to 63 mm. long, but are similar in coloration to those of Goodland Point in a series of 20 taken in 1904 and 1907. Similar shells were taken by Mr. Moore in February, 1907, at the north end of Horr's Island, 21 living specimens.

Gomez Old Place, a key southeast of Goodland Point, 48 living specimens, 1906, similar to those of Goodland Point except in being smaller, 45 to 51 mm. long.

Russell's Key (Pl. XXXVIII, figs. 12, 12*a*, 12*b*). A subvariety was found here differing in its greater solidity. There is *no trace of yellow bands on the dead-white surface* at any stage of growth. Yellowish-olive lines are often present on the last half whorl. The *subsutural and peripheral bands are bright pink* and comparatively wide. The columella is of the heavy, straight, truncate type in all young and about 33 per cent of the adult shells, but non-truncate and

continuous in the majority of adults. The size varies from length 56, diam. 27 mm. to length 65, diam. 30 mm.

The total absence of yellow, even in the young, gives this colony a very distinct appearance. It is an incipient race. 109 living and some dead shells were taken by Mr. Moore in 1904 and 1906.

Turner Place or Key, Turner River, Lee Co. The typical *L. f. roseatus* was found in 1904 and 1906 not distinguishable from those of Goodland Point. The young, 30 to 34 mm. long, have two rather bright yellow bands, which finally disappear, leaving the last whorl white with green and reddish lines. At the same time, the yellow band on the spire fades more or less in the living snail, so that it is not conspicuous in the adult stage. 6 living specimens. This place is near Chokoloskee.

East Cape, Cape Sable (Pl. XXXVIII, fig. 15). The pure *roseatus* occurs here with *two broad yellow zones*, which fade with advancing age, but usually continue to the lip. *Greenish lines are wholly wanting or but faintly visible* behind the lip; the sutural pink border of typical *roseatus* is reduced to a narrow yellowish line or wholly wanting, and there is *no pink or yellow peripheral line.* The size of adult individuals varies widely. The shell is solid, usually with thick, truncate columella but sometimes it is less thickened, with the columella narrower and continuous. The coloration varies in intensity, some shells being as pale or paler than fig. 13, others brighter yellow than fig. 15, but otherwise it is constant in 54 shells taken by Mr. Moore.

Length 44, diam. 23½ mm. (average specimen).
Length 52, diam. 27½ mm. (widest specimen).
Length 56, diam. 28 mm. (largest specimen).
Length 39½, diam. 21 mm. (smallest adult specimen).

The occurrence of a pure race at this place is anomalous in view of the hybrid races found both eastward and at middle Cape Sable. It is quite possible however that the colony has been isolated a long time by pine land or swamps, preventing the access of *castaneozonatus;* or it may possibly have started from pure (recessive) individuals of *roseatus* from a mixed colony. A knowledge of the local topography at East Cape and inland might give a clue to the problem.

3. Pure Roseatus Colonies from the Keys North of Largo.

In this area the *roseatus* forms resemble those of West Florida, but are usually smaller, more inclined to xanthism and often more extensively pink. The series was collected by Mr. C. B. Moore. The localities are plotted in fig. 3, page 441, and fig. 5, page 442.

The group of keys north of Largo, including Big and Little Palo Alto, Totten's, Porgy and Old Rhodes, are inhabited by a race of *L. f. roseatus* in which the pink color is exceptionally bright. The size is usually rather small, and often

a pink peripheral line is present, as in western Florida. The series is particularly interesting because of the minor modifications which give an individuality to the forms of each key. Incipient races have evolved from the original stock, the formation of channels having cut the former area into keys isolating the colonies. Big Palo Alto, the last to be dismembered from Largo, received a tincture of the *castaneozonatus* stock, which came too late to reach the keys further north. The spreading of *roseatus* northward was arrested by the deep Cæsar's creek, flowing between Old Rhodes and Elliott's Key, which was probably established before the other and shallower channels. The salient features of these colonies of *roseatus* are as follows:

1. *Roseatus* with colors like those of the Largo hybrid race, Pumpkin Key.

2. Like No. 3, but with a small admixture of *castaneozonatus*, Big Palo Alto Key.

3. Ground white, inclining to rose; spire extensively pink; a pink subsutural and yellow peripheral line. Shell larger, Totten's Key. Shell smaller, Little Palo Alto Key.

4. Ground largely yellow in two broad zones, spire extensively pink.

(*a*) Zones deep yellow; peripheral line pink or pinkish yellow. Porgy Key.

(*b*) Zones pale yellow; peripheral line very faint or wanting, Old Rhodes Key.

(*c*) Zones faint yellow, wanting on the last whorl, Adams Key.

Pumpkin Key. 40 specimens taken by Mr. Moore in 1904 are chiefly (75 per cent) yellow tinted on the last half whorl, with several green lines or none above the periphery, and numerous wider yellow bands below. Others (25 per cent) are pinkish-white with very faint lines only; but several of them have added a yellow edge 5 to 8 mm. wide, to the lip. In all, the sutural line is wanting or weak. A yellow peripheral line is visible in about half of them. They are more like Largo *roseatus* than like the following lots, but in a series of 40 there are none of the dark-zoned or *crenatus* forms. These *roseatus* differ from those of the West Coast in the thinner shell and columella. The latter is either continuous or truncated at the base. In young shells the columellar truncation is generally much more distinct and the axis itself is heavier. They are like West Coast *roseatus*, while the later stage diverges.

Totten's Key (Pl. XXXVIII, figs. 18, 18*a*). The shells are rosy white with a large part of the spire beautiful rose color. The last third or half of a whorl is pale yellow, following a growth-arrest (fig. 18*a*). When the change comes later, the yellow is the more marked (fig. 18). In every one of the 43 specimens, the peripheral belt is visible, and it is usually quite conspicuous and bright yellow. In two shells it is pink. A narrow pink sutural line is invariable. About 60 per cent of the shells have no greenish lines, and these are numerous on only about 10 per cent. The usual length is about 50 mm., but the largest is 58 mm. long.

Little Palo Alto Key. The specimens are entirely similar, except that they average smaller than those of Totten's Key.

Porgy Key (Pl. XXXVIII, figs. 19, 19*a*). 25 specimens collected by Mr.

Moore, April, 1904. The race is similar to that of Totten's Key except that the tendency to xanthism is far more marked. *The last 2 whorls are yellow, the last one intensely so.* There is a pale border below the pink sutural line and a pale band above and below the wide yellow or pinkish peripheral girdle. The only variation from the above is in one specimen like fig. 18 (of Totten's Key) and another resembling fig. 18*a*. The size is from 46 to 56 mm. long.

Old Rhodes Key at the north end (Pl. XXXVIII, fig. 13). The shells are *broadly two-banded with yellow*, but the bands are often indistinct, more intense at places of growth-arrest. They become fainter with growth, and in mature shells the stronger yellow of the earlier whorls is partially lost by fading. A few faint greenish lines appear on mature shells. There is *no peripheral belt* of yellow or pink. As in the neighboring colonies, the first 4 or 5 whorls are pink. This form is perhaps nearest to that of Porgy Key, but is also related to the Adam's Key race. Out of 22 taken, only four have attained full size. These measure:

Length 45, diam. 22, aperture 20 mm.
Length 44, diam. 23, aperture 21 mm.
Length 40, diam. 21, aperture 19 mm.
Length 40, diam. 23, aperture 20 mm.

Adam's Key, a tiny key at the lower end of Elliott's, afforded two living specimens of a form almost exactly like that of Turner Key, in the Ten Thousand Islands, West Florida. The only difference is that the East Florida form is not quite so heavy. The white shell has a small pink apex. On the median neanic whorls there is a yellow zone, which is wanting on the last 1¾ whorls. On the latter part of the last whorl, green lines and a reddish peripheral band appear. The young shells of this race will be like those of the Old Rhodes Key race—broadly two-banded with yellow. The two shells are adult and measure:

Length 54, diam. 27, aperture 26½ mm.
Length 47, diam. 25, aperture 23 mm.

The minute resemblance existing between the Adam's and Turner Key forms is evidently adventitious, and due to the rather primitive coloration of both, while in the neighboring colonies there has been specialization of color.

4. Hybrid Colonies of roseatus × castaneozonatus from the West Coast.

Chokoloskee Key, Monroe Co. (Pl. XXXVIII, figs. 14, 14*a*–*e*). A chestnut-zoned form (*castaneozonatus*) is here superposed upon the typical *roseatus*, all of the four lots before me being hybrid colonies. With the exception of four specimens to be mentioned below, the shells, 1,157 in number may be divided into *roseatus* and *castaneozonatus*. The *roseatus* form is exactly like those of Goodland Point and adjacent localities. The white form with some green or

yellowish-olive lines (rarely wanting) on the last half of the last whorl is the predominant pattern (Pl. XXXVIII, figs. 14, 14*a*), others having two yellow bands also (Pl. XXXVIII, fig. 14*b*). The columella varies from straight and heavy to thin, in all the color-forms, as in Marco Island *roseatus*.

The *castaneozonatus* form is variable in the amount of chestnut coloring (Pl. XXXVIII, figs. 14*c*, *d*, *e;* text figure 12). The pattern begins on or at the end

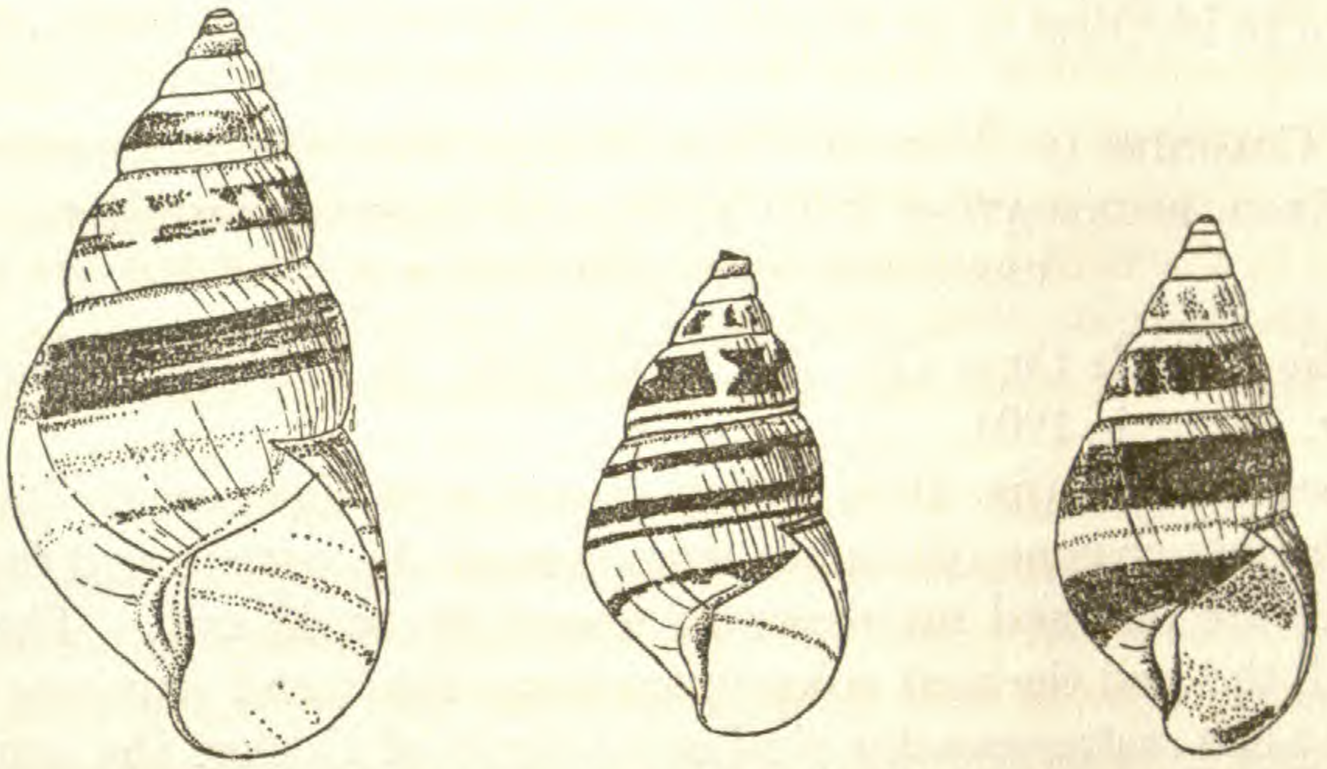


FIG. 12. *Liguus fasciatus castaneozonatus* from the hybrid colony of Chokoloskee.

of the fourth whorl in most adult examples, as a series of oblong spots. In well-preserved or young shells it is faintly visible earlier, on the last embryonic whorl. On the penultimate whorl the spots spread to form a continuous or interrupted zone, which usually continues on the last whorl but rarely reaches the lip. A similar basal zone is occasionally developed. Probably through impotence of the color-factor for chestnut, the zones are often very imperfectly developed, as in fig. 14*c*. Their upper and lower borders are apt to persist when the middle of the zone is weak or wanting, a narrow-banded pattern being thus produced (text figure 12, middle fig.). The chestnut zones appear on both the white and the yellow-banded *roseatus* ground-colors described above.

The color-patterns are in the following proportions:

(Lot collected alive by Mr. Moore and assistants, 1904 and 1906.)

Roseatus pattern { white ground, 198 = 48.53 per cent.
yellow-banded, 35 = 8.58 per cent.

Castaneozonatus pattern...175 = 42.9 per cent.

(Lot collected by C. G. McKinney from ground cleared by him, 1905.)

Roseatus pattern { white ground, 224 = 30 per cent.
yellow-banded, 98 = 11.7 per cent.

Castaneozonatus pattern...421 = 56.6 per cent.

In the lot collected by Mr. McKinney, in the course of clearing four acres of hammock land there are four shells (Pl. XXXVII, fig. 10) exactly like the darkest "*marmoratus*" found at Key Vaca. The first four whorls are *white*,

a brown pattern of irregular oblong markings then appearing. The last 2½ whorls are white at suture, periphery and columella, elsewhere black with some white spots, and bluish zones in the middle of the upper and lower surfaces. The green lines of ordinary *L. fasciatus* are represented by obscure black lines. *The columella is white* and either of the thick, straight and truncate type (2 specimens) or of the thin, narrow type (2 specimens).[16]

Rabbit Key. Only dead shells, part of them retaining some color, were found. They seem to be identical in all respects with the Chokoloskee hybrid race.

4. Hybrid Colonies of Middle Cape Sable and the Southern-central Keys, segregating into roseatus, castaneozonatus, crenatus and marmoratus.

Cape Sable, Middle Cape (Pl. XXXVIII, figs. 16, 16*a–d*). Two small lots taken by Mr. Moore in 1904.

1. Thirteen *crenatus* (fig. 16*d*), yellow-tinted with light-green lines or white with few pale lines or none (probably from loss of the cuticle and fading). All of these shells are thin and rather small, length 40 to 45 mm. The columella varies in both this and the next color-forms from thick and truncate to narrow.

2. Twenty-one *castaneozonatus* similar to those of Cutler, the zones varying from nearly continuous, fig. 16*b*, to mere traces. Form rather capacious, length 42, diam. 24.5 mm., or more slender, length 41, diam. 22.5 mm. The suture has a pale yellow marginal line or none, periphery with a similar narrow band or none. The inner lip has purple vortex-stripes and a purplish brown or rose-brown outer stripe (Pl. XXXVIII, figs. 16, 16*a*, *b*).

3. Two "tortoise-shell" pattern similar to those of Cutler except that the subsutural tessellation is less marked, the band being nearly continuous in one of them, fig. 16*c*.

The hybrid race from this place does not differ materially from that of Cutler and adjacent localities on the east coast.

Southern-central Keys. The group of keys comprising Duck, Grassy, Crawl, Fat Deer, Vaca and their satellites, occupies a south-central position, and lies between Matecumbe, etc., where only *Liguus crenatus* dwells, and the south-western group of keys, upon which only *Liguus solidus* and its mutations occur. It is somewhat remarkable that the prevalent races of *Liguus* upon these south-central keys are related to those of Middle Cape Sable instead of to the races of the keys on either side. The distribution of *Oxystyla floridensis* also suggests that there has been in the past a connection between the Cape Sable region and the southern keys closer than now exists. The faunal evidence points to a land connection, which now remains as extensive shoals within the

[16] While there is not the slightest ground for doubting Mr. McKinney's good faith, it seems likely that the four *marmoratus* in his lot were really shells which had been brought from Key Vaca and inadvertently put with the lot he was keeping for Mr. Moore, without his knowledge that they were foreign to Chokoloskee. It seems quite incredible that *marmoratus* could arise in a *roseatus* × *castaneozonatus* colony.

6 foot line, extending with little interruption from Grassy and Duck Keys to the mainland. Long Key, which may belong to this group of keys, is "a long strip with vegetation hardly suited to *Liguus*. *Drymæus* was found on the low bushes" (C. B. Moore).

Grassy Key (or Big Grassy Key). The hybrid race *roseatus* × *castaneozonatus* was taken. Both forms are very similar to those of Chokoloskee Key, drawn in figs. 14, 14*e*. Mr. J. S. Raybon, who collected these shells for Mr. Moore in 1904, reports dead shells in abundance, but only three living ones found after a long search, although the hammock appears very favorable. Two specimens of *crenatus* are in the collection of the Academy, collected about twenty years ago by Mr. Joseph Willcox. They are like the Duck Key form. No *crenatus* were among the few Grassy Key shells taken by Mr. Raybon.

West Crawl Key, searched by Mr. Raybon in 1904, afforded only quantities of long-dead fragments, one of which shows the bands of *castaneozonatus*. It is evidently the same race as that on Grassy Key.

Duck Key. A few fragments, the last whorl only, were taken by Mr. Raybon in 1904, the freshest one not unlike the form of *crenatus* from Grassy Key and Middle Cape Sable, shown in Pl. XXXVIII, fig. 16*d*. As the other fragments are too old to show color I leave the form among those of adjacent keys, since it would probably prove to be a hybrid race if adequate material was available.

Key Vaca. Dead shells of the same *roseatus* × *castaneozonatus* hybrid race were taken in 1904 by Mr. Raybon on Key Vaca in an old field about three miles west of the middle of the key.

Key Vaca (Pl. XXXVII, figs. 9, 9*a–d*). About midway of Key Vaca Mr. Raybon (1904) found eleven living *Liguus*. The shells are thin, *long-spired* composed of 7 to 8 whorls. The columella is of the thin *crenatus* type. Coloration as in pale *crenatus* (white or xanthistic) in some shells, but in others peculiarly marbled with deep brown or black over *crenatus* ground. The marbled form, which may be called *marmoratus*, is probably a new mutation of *crenatus*, or of *crenatus* × *castaneozonatus*, which now forms a considerable element in the race. The color forms represented are as follows:

1. Plate XXXVII, fig. 9*c*. White, with a few olive-yellow or olive-green lines on the last half whorl, four shells. Another is similar except for its very pale ochre tint.

2. Plate XXXVII, fig. 9*b*. Similar but strongly xanthistic, also with olive-green lines, two shells.

3. Pale ochre, brightest near the lip, with the very tip of the apex, and streaks on the parietal wall roseate, an area around the columella purple; one shell.

4. Plate XXXVII, figs. 9, 9*a*, 9*d*. Embryonic and first neanic whorls white, spirally striate; on or at the end of the fourth whorl small brown spots in spiral series appear above and below the sutural white borders. About a whorl further on the spots of the lower series become confluent into a blackish-chestnut band, from which wide black or purple-brown flames rise to the spots along the suture

above. On the last two whorls the flames become more or less confluent, covering the surface except for curious oval or flask-shaped light spots, a narrow white margin above and below the suture, and on the last whorl there is a light band at the periphery and a small columellar light area, which is yellow in xanthistic shells, violet in those with white ground.

This form is like the melanistic specimens said to be from Chokoloskee, and differs from those of the east coast chiefly in lacking any tendency in the dark flames to split or fork above. Such splitting produces a subsutural tessellation in the Miami race, which is absent in *marmoratus*. In this Vaca form, the melanistic mutation has been superposed upon a slightly larger, longer race than at Miami. A specimen of *marmoratus* has been figured by W. G. Binney, *4th Supplement to Terr. Moll. V*, pl. I, fig. 5. It was collected by Hemphill on Key Vaca in 1883. Nine of the shells from Key Vaca measure:

Length 54, diam. 27, aperture 25 mm. (apex truncate).
Length 56.5, diam. 26.5, aperture 25.5 mm. (apex truncate).
Length 50, diam. 26, aperture 23.5 mm.
Length 57, diam. 26, aperture 23 mm.
Length 46, diam. 21.5, aperture 20 mm.
Length 53, diam. 25, aperture 24 mm. (*xanthistic*).
Length 58, diam. 26.5, aperture 25 mm. (*marmoratus*).
Length 53, diam. 24.5, aperture 22.5 mm. (*marmoratus*).
Length 45, diam. 24, aperture 21.5 mm. (*marmoratus*).

In the blackest examples, as fig. 9, the green lineation of *crenatus* is represented by obscure lines visible only in certain lights.

This *marmoratus* form is parallel to but not in any way directly connected with the East Coast tortoise-shell form (*testudineus*).

5. Hybrid Colonies composed of crenatus × roseatus × castaneo-zonatus, and segregating into three or four patterns.

On the west side of Biscayne Bay, south of the Miami River, the colonies of *Liguus* are heterogeneous, consisting of the forms *crenatus*, *roseatus*, *castaneo-zonatus* and *testudineus* or "mosaics."

It was the experience of Mr. Rhoads, Mr. Moore, and myself that the darkest forms are to be found only in the most dense and shady hammocks; where also the richest yellows occur. The paler races are found copiously with them,—everywhere the most abundant form; but they have also a wider range in more open and therefore lighter woodland. The significance of this selective distribution is not clear. It may be that the food-fungus in the more shaded, humid woods affects the amount of dark pigment deposited in the shell.

1. Plate XXXIX, figs. 20 *m*, *n*, *o*. The most abundant form, *crenatus*, has a ground of either white throughout, or deep yellow on the last whorl or two,

in either case being decorated with grass-green, olivaceous or yellowish lines. The yellow is rarely disposed in two wide zones. The columella varies from the typical thin, continuous *crenatus* structure to a thicker, truncate form as noted under *roseatus*. The sutural line is white.

2. Next in point of numbers is the *roseatus* type. The specimens are thin, and except for the presence of pink vary in color exactly like the *crenatus* form. The columella is usually truncate, but not very thick. There are no pink lines at suture or periphery, and occasionally the apical whorls are white. The *roseatus* component of this hybrid race is therefore decidedly unlike the West Florida *roseatus*, its characters being decidedly modified apparently by the mixture with *crenatus*. Occasionally pink is visible only as a faint wash on the parietal wall.

3. Pl. XXXIX, figs. 20*g*, *h*, *i*, *j*. The *castaneozonatus* form is here as elsewhere superposed upon the *roseatus* type only, never upon the *crenatus* type, doubtless because in hybrids with *crenatus* rose color is dominant over white. The dark band is composed of numerous oblong spots, which on the penultimate or next earlier whorl tend to coalesce by groups of two, three or more, forming an interrupted band. This only rarely extends upon the last whorl in adult shells, and never to the lip. A lower or basal band is usually present in young, rarely in adult shells. Otherwise the patterns are as in *roseatus* described in the last paragraph. The parietal callus varies from pale rose to dull purple. This pattern of coloring intergrades with *roseatus* through specimens, such as fig. 20*j*, which show only a few faint traces of chestnut. By its usual presence only in the period of youthful rapid growth, it appears that in the Miami colony chestnut banding is decadent. Its factor in heredity is becoming impotent.

In Miami *crenatus*, *roseatus* and *castaneozonatus* it is possible to assort most specimens into (1) smaller, heavy forms, with truncate collumella, and (2) larger, thinner ones with the columella nearly or quite continuous. In a lot taken at random from the hammock on the south side of the river, opposite Miami, the proportions of these several forms are as follows.

Color-type, etc.	Thin form.	Heavy form.	Total percentage of each color-type.
crenatus	24 per cent.	16 per cent.	40 per cent.
roseatus	8 per cent.	18 per cent.	26 per cent.
castaneozonatus	20 per cent.	14 per cent.	34 per cent.
Average weight	.08 oz.	.11 oz.	

In all hybrid and some pure colonies of Floridan *Liguus*, the character of the columella varies independently of the color. The heavier, truncate type prevails in the young stages, and is also phylogenetically older, *L. fasciatus* of Cuba and other related species having this type of columella.

4. Plate XXXVIII, figs. 20, *a–f*. The fourth element in the Miami *Liguus* series is the so-called tortoise-shell snail, form *testudineus*, which may perhaps, in

the absence of data from breeding, be considered a hybrid mosaic. There is no intergradation between the "tortoise shell" race and the others, and no other varies towards this one in the slightest degree.

The shell varies from rather solid to thin; and the columella may be either callous and truncate or thin and continuous. The apex and columella vary from white to pink, but both are usually pale. This indicates its hybrid nature. From the fact that tortoise-shell *Liguus* are everywhere rare and greatly outnumbered by other forms, and are extremely diverse in coloring, it seems possible that the form is incapable of existing as a pure race, like yellow mice or Blue Andalusian fowl.

The ground-color is usually yellow but varies to almost white. The pattern consists fundamentally of broad, sinuous dark flames which *fork below the white sutural line* producing a tessellated border, often smeared with reddish. The flames terminate in a dark band *at the periphery*, which is bordered below by a light girdle. The base is radially streaked. Over all of this there are the usual green or olive spiral lines, when these are not lost in general melanism. The principal modifications are as follows: (1) more or less complete interruption of the flames, which remain only as tessellated subsutural and peripheral bands (Pl. XXXIX, fig. 20*e*, 20*f*). (2) Modification of the color of the flames, which may be green or blue in the middle, rich brown or black at the end (figs. 20*a*, 20*c*). (3) Coalescence of the flames, producing black shells with light spots and streaks (fig. 20, 22*h*).

This is the most richly pigmented of all the Floridan *Liguus*. Some specimens present wonderfully beautiful combinations of color. The coloration, while greatly intensified in some and diminished in other examples, yet shows no variation in the fundamental pattern. It occurs most frequently in the densest hammocks and only as scattered individuals among great numbers of the other color-forms. No *testudineus* have been found north of Miami river.

It is impossible to calculate the proportions in which *testudineus* occurs because none of the sufficiently large lots from Miami are strictly unselected. The importance of unselected series was not realized when they were collected, and an undue proportion of the rare forms was gathered.

The above notes and figures 20, *a–m*, apply to specimens from the hammock near the mouth of the Miami river opposite the town, collected by Messrs. C. B. Moore, S. N. Rhoads, H. A. Pilsbry and others. From the south side of the Miami River one mile up specimens similar to those from near the mouth were taken by Mr. Moore in 1904.

North of the Miami River the *roseatus* × *castaneozonatus* × *crenatus* hybrid occurs. The shells are of the Miami type, but there are no *testudineus* among them; but both lots taken are so small that conclusions drawn from them must be taken with reserve. In the small series taken on the north side of Miami river, about 2½ miles up, there are 8 *castaneus*, 5 *roseus* and 6 *crenatus*. At Arch Creek, nine miles north of Miami, near the head of Biscayne Bay, Messrs.

Moore (1904) and Rhoads (1906) found 4 *crenatus*, 7 *roseus*, 2 *castaneus*, of the ordinary Miami type. Mr. C. T. Simpson also found the same forms there in February, 1905. No hybrid race has been found further north.

Hammock ½ mile south of U. S. Agricultural Experiment Station of Plant Diseases, near Miami, collected by S. N. Rhoads February, 1906. Shells are of the Miami type. All seen were taken, the proportions being as follows: *crenatus*, 115 specimens, *roseatus* 39 specimens, *castaneozonatus*, 24 specimens, *testudineus* 17 specimens. The proportion of *testudineus* is much greater than in any other Miami lot.

Brickell's Hammock; collected by Professor J. W. Harshberger, December, 1910, and August, 1911. *Crenatus* and *castaneozonatus* of Miami patterns. One of the *crenatus* is figured, Pl. XXXIX, fig. 20*n*, in which part of the lines are green, part yellowish olive.

Cutler, about twelve miles below Miami, collected by Mr. C. B. Moore, 1904 (Pl. XXXIX, figs. 22 *a–h*). *L. f. crenatus* with olive or olive-green lines on yellow ground fading on the spire, or on white ground, very largely predominate in all situations here, according to Mr. Moore's note. None were found with bright green lines. *Roseatus* appears to be comparatively rare. In *castaneozonatus* (figs. 22 *a*, *b*, *c*, *d*) the zones are frequently black and continuous or nearly so on the last whorl, where they often continue to the aperture, as in the Key Largo form. Unlike the latter, they are broken on the spire, as in the Miami form. In a series of 32 adults, the upper zone extends upon some part of the last whorl in all, and the basal zone is developed in 30. The very dark forms are chiefly found in very thick woods according to Mr. Moore, but also associated there with many of the pale *crenatus* type.

In one of the Miami lots there are 30 *castaneozonatus*, of which number neither brown zone extends to or upon the last whorl in 19; the upper zone only in 2, and both bands in 9 specimens, though in only three of these are they conspicuous on the last whorl. The comparison may be tabulated thus:

		30 Miami Shells.	32 Cutler Shells.
Two zones or series of brown spots representing them...	Both extending on last whorl	9	30
	Upper zone only on last whorl.....	2	2
	Neither extending upon last whorl 19		0

The Cutler colony is thus much more melanistic than that of Miami, resembling the Largo form in this respect. The interruption of the band into flames on the neanic whorls is unlike the Largo colonies, and similar to that of Miami.

The *testudineus* form (Pl. XXXIX, fig. 22*h*) was found rare at Cutler by Mr. Moore. Only five were taken, although the dark shells were especially looked for. These are extremely melanistic, being black with some yellowish spots, the early whorls and columella white. None of the green or blue marbled specimens were taken, such as occur between Miami and Cutler.

Homestead, 28 miles south of Miami, collected by S. N. Rhoads, February, 1906. Several dead specimens of *L. crenatus*.

Detroit, thirty miles south of Miami. Plate XXXIX, fig. 21. Collected by Professor J. W. Harshberger, August, 1911, and Mr. Morgan Hebard, July, 1912. Rather solid yellow *crenatus* with a pale or white peripheral band, white spire, and faint olivaceous lines on the last half whorl. The small series of 6 living specimens is hardly sufficient to show whether this form occurs as a pure race. I have provisionally included the Homestead and Detroit colonies in the Miami series from their geographic position. The small number of shells seen is quite insufficient to show the composition of the colonies.

Key Largo. Collections were made by Mr. Moore at three points: near Planter, not far from the south end of the Key; back of Point Charles, and near the north end of the island. Mr. Morgan Hebard took specimens at Largo Station near the middle of the island.

The chief characteristic of the key is the rich development of the chestnut-black two-zoned race. The mixture of forms is otherwise as on the mainland except that none of the "tortoise-shell" form has been found.

Two miles east of the town of Planter, near the south end of the key an unselected series of 73 shells was taken by Mr. Moore in 1904. The thin, narrow type of columella prevails in all of the color-forms, but some shells have the heavy, truncate type.

1. *Crenatus:* white ground 34; diffuse yellow, often bright, the spire white, 14; lines rather sparse, chiefly light olive; no colored subsutural line. Also three specimens of the yellow form having roseate parietal wall but white apex and no sutural line, thus uniting characters of *crenatus* and *roseatus*.

2. *Roseatus:* Broadly two-banded with yellow, scattered lines and a sutural line olivaceous-yellow, 12.

3. *Castaneozonatus:* With ground-pattern of the *roseatus* type, 10, of which four have broad blackish bands, the others imperfect bands.

Largo Station, collected by Morgan Hebard. 12 specimens of the following forms:

1. *Crenatus,* white with a few faint yellowish-olive lines on the base, 2 specimens.

2. *Roseatus,* with a few yellow or pale green lines, 4 with two broad deep yellow zones (Pl. XXXIX, fig. 23*b*), 3 with very pale yellow zones.

3. *Castaneozonatus,* with zones like fig. 22*a* or with a few chestnut smears only, in either case over a deep yellow-zoned ground, 2 specimens.

Hammock back of Point Charles, Key Largo, collected by Mr. C. B. Moore, 1904 (Pl. XXXIX, figs. 23, 23*a*).

No *crenatus* in the series of about 80 shells. The *roseatus* form is like that from near Planter except in being larger. *Castaneozonatus,* figs. 23, 23*a*, is peculiar in that the dark band is almost unbroken on the early whorls, showing no trace of its origin as a series of longitudinal stripes or spots. This is a highly accelerated or evolved condition not found in any other colony. Only a small proportion of the shells are broadly black-banded to the end, the bands usually weakening on the last whorl or two.

Near the north end of Key Largo a large series shows the same forms found near Planter. The *castaneozonatus*, as at Planter, has a series of spots preceding the continuous band. Pl. XXXIX, fig. 24, shows a rather unusual color-form, others resembling figs. 23*a*, 23*d*. Several other lots not exactly localized on the Key also agree with the Planter series.

Big Palo Alto Key (Pl. XXXVIII, figs. 17, 17*a*). In the lot of 60 collected there are no *crenatus*. The *roseatus* resemble those of Little Palo Alto and Totten's Key; the peripheral line is usually wanting but sometimes distinct and brownish-pink. Most specimens show some traces of olive-green or yellowish lines. Few show faint yellow bands, the general tint being faintly rose-white. The pink of apex, columella and parietal wall is intense.

There are two typically marked *castaneozonatus* of the Largo pattern, and five with the pattern imperfectly present on the spire, as in fig. 17*a*. Several of these, and some of the *roseatus* have one or more oblique purplish streaks at the varices or resting stages, like the race of Lignum Vitæ Key. This has not been observed in any other *Liguus* of the east coast keys.

Except in having a small number, about 11 per cent, of *castaneozonatus*, these shells closely resemble those of the adjacent keys, Totten's and Old Rhodes.

6. Race of Lignum Vitæ Key, Liguus fasciatus lignumvitæ.
Plate XXXVII, figs. 4, 4*a*–4*d*.

Of the race from Lignum Vitæ Key I have seen 100 specimens taken by Mr. Moore in 1904 and four taken by Mr. Joseph Willcox about 1886. It has an elaborate pattern of brown and bluish streaks and flames, and brown and green spiral lines, superposed upon a pale ground resembling *L. f. roseus*.

The shell is invariably *thin*, with a long, straightly conic spire; whorls 7 to 7½. The ground-color below the roseate apex is pale rose-white, or the last whorl may be pale sulphur yellow, always with a narrow white band below the suture, a wide one at the periphery.

The pattern varies, beginning with (1) oblique brown flames, which appear on the third whorl, and continue to the end of the embryonic stage (see text figure 2, page 436). After a brief interruption they are resumed for the distance of a whorl, more or less, when a partial interruption usually occurs, where only series of spots near the upper and lower sutures remain. (2) This interruption, when it is present, is followed on the fifth or sixth whorls by wider flames of purplish or bluish color, irregular in form and distribution. The series of spots near both sutures remains; a brown sutural line, and one at or near the lower suture appear, the latter becoming peripheral on the last whorl. On the penultimate whorl the flames become rare; and on the last whorl (3) they are replaced by a few bluish oblique variceal or growth-arrest streaks. The sutural and peripheral lines and spot-series continue. Usually there are numerous green spiral lines upon the last whorl.

The thin parietal and columellar callus is pale pink. The columella is thin,

vertical and simple, not truncate in front view. There is much variation in the degree of acceleration of the flame-pattern, the several successive sets of flames being crowded on some shells so that they can scarcely be distinguished, while on others the breaks in the series may be a half-whorl long and are conspicuous. These variations are continuous. The development of dark variceal streaks as the regular mode of ornamentation of the ephebic stage is a somewhat unusual feature of this subspecies, but occurs also in *L. solidus graphicus* and in the race of *L. fasciatus castaneozonatus* from Big Palo Alto Key.

A notable discontinuous variation appears in 8 specimens (8 per cent of the whole number collected by Mr. Moore), in which all brown or purplish flames and bands are wanting, the shell retaining only the white and yellow ground-color and green lines. The apex and columella are pink, as in all other specimens. This variation—the absence of brown pattern,—occurs also in other races of *Liguus* (Pl. XXXVII, figs. 4*c*, 4*d*).

Liguus fasciatus lignumvitæ is closely related by its color pattern to typical *fasciatus* of Cuba, which differs by its much greater solidity and less convex whorls. It is also related to *L. solidus graphicus*. It differs from the latter by having invariably green spiral lines. I do not believe that the race is related directly to any forms of the mainland or east Florida. It seems to be a descendant of the Cuban *fasciatus* stock which also gave rise to *L. solidus*. It is entirely different from the *Liguus* of the keys adjacent to Lignum Vitæ, or from those of the south-central group of keys.

7. Race of the Southwestern Keys, Liguus solidus.

Plate XXXVII, figs. 1, 1*a*, 1*b*, 2, 2*a*.

From Pine and No-Name Keys westward to Key West the forms of *Liguus* differ so much from those of other Floridan localities that they may conveniently be separated as a species under the name *Liguus solidus* (Say). The shell is solid, the surface having a porcellanous smoothness and gloss; there are *never green, olive or yellowish spiral lines;* and the broad yellow zones do not become darker towards the lip, as they do when present in *fasciatus*. The patterns of color are unlike those of *fasciatus*, and have more fundamental resemblance to the patterns of the Cuban forms *murreus* and *blainianus*, which also lack green lines.

The area occupied by *L. solidus* does not overlap that of *L. fasciatus*, which extends as far west as Key Vaca. The locality and collector of the type of *L. solidus* were given by Say as "East Florida, T. R. Peale."[17] Through the kindness of Mr. S. N. Rhoads, who possesses Peale's MS. journal, I have been able to fix upon Key West as the type locality of *L. solidus*.[18] Say's original specimen is still preserved in the collection of the Academy.[19]

[17] *Journal of the Academy of Natural Sciences*, V, p. 122.

[18] Peale spent the winter of 1824–5 in Florida. Early in 1825 he left St. Augustine, where he had been for some time, for a sea trip to the Keys. The first stop was at Key Tavernier, February 5;

Color-forms.—L. solidus occurs in four conspicuously dissimilar color-forms as follows:

Without brown markings.	I. Shell with white or pale bands at the suture, periphery and base, broad yellow areas between them; upper whorls and mouth white. (Form *solidus* Say.) Pl. XXXVII, fig. 1*b*.	III. Shell white with yellow bands at suture and base, and two contiguous ones at the periphery; apex and aperture white. (Form *solidulus* Pils.) Pl. XXXVII, fig. 2*a*.
Having brown markings.	II. White and yellow as above, but a brown line divides the peripheral white band, and another borders the suture. Yellow zone traversed by dark flames on the spire, persisting usually as bordering spots on the last whorl. Apex and columella pink. (Form *graphicus* Pils.) Pl. XXXVII, fig. 1, 1*a*.	IV. Brown blotches disposed in series occupy the positions of the yellow bands described above, a brown line running between the two contiguous peripheral spot-bands. The rest of the last two whorls is yellowish; apex pink; some dark flames, chiefly on the spire. (Form *pictus* Rve.), fig. 2.

It will be noticed that forms I and III are albinistic, differing from II and IV respectively by lacking dark color-markings, and in no other respect. They occur in colonies of the colored forms, and in small numbers. This would lead to the conclusion that no dark pattern is recessive to dark pattern.

The form no. II, which I have called form *graphicus* (Pl. XXXVII, figs. 1, 1*a*) has apparently a more primitive color-pattern than the others, the flame-painting of the neanic whorls resembling that of Cuban forms of *Liguus*, and conforming to the fundamental pattern characteristic of *Oxystyla*, *Orthalicus* and their South American allies of the same subfamily. The flame pattern has been accelerated to extend upon the last embryonic whorl, and it has been largely lost on the last whorl, or reduced to series of blotches forming bands bordering the peripheral white belt. The decadence of dark pattern on the last whorl or two, leaving it fully developed only in early youth, indicates that evolution is in progress towards a shell with spiral bands of white, yellow and brown, but no axial markings.

As form II, *graphicus*, has been found on several of the keys inhabited by the species, and 86 per cent of the shells seen are of that pattern, it is evidently the dominant form. It is also the oldest pattern phylogenetically.

Form I, *solidus* (Pl. XXXVII, fig. 1*b*) has been derived from *graphicus* by loss

then "Ad. Night's Key near Key Vacas," February 6; and the following day they made Key West. At both of these Keys Peale mentions collecting crustacea, mollusks, etc., but without mentioning land shells. *Liguus* probably occurs on neither of them. On February 9 Peale landed on Key West to hunt, "but found nothing but some shells." On the 13th they landed on Sand Key, and February 14 on Boca Chica, where he "found some fine shells." On the 21st, having returned to Key West, Peale "*collected land shells which we found in great abundance on the trees, some of them very handsome.*" Subsequently, March 2, he landed on one of the islands near "Bayou Honda" [Bahia Honda] to hunt, and "found a few good shells." From this account, it seems very likely that Peale got the type of *Liguus solidus* on Key West, this being the only place where he mentions finding land shells. The "very handsome" shells "on the trees" could hardly have been anything else than *Liguus solidus*.

[18] This specimen is slightly abnormal in shape, apparently owing to a fracture while young. It has been figured in the *Manual of Conchology* (2), XII, Pl. LVIII, fig. 86.

of the black-brown and the pink pigment. It is an albinistic form, the exact constitution of which can be learned only by breeding.

The form IV, *pictus* (Pl. XXXVII, fig. 2) has bands of brown spots and form III, *solidulus*, has yellow belts where the other two color-forms have white, unpigmented bands. They are *negatives*, so to speak, of the others. Yellow in them takes the place of white, in the others, and white replaces yellow. *Pictus* is apparently a mutation (in the de Vriesian sense) of *graphicus*, parallel to the mutations *marmoratus* and *testudineus*. Form *solidulus* holds exactly the relation to *pictus* that *solidus* does to *graphicus*. These forms are everywhere excessively rare at the present time, and possibly extinct.[20]

Dimensions.—In the larger keys the ordinary adult length of *L. solidus graphicus* and *solidulus* is about 58 to 65 mm. The *pictus* and *solidus* seen are smaller. When not otherwise stated the dimensions below are of the *graphicus* form.

No-Name Key. Collected by Pilsbry and Simpson, 1907.

Length 70 mm.;	diam. 31	mm.;	length of aperture 31	mm.
Length 67 mm.;	diam. 30	mm.;	length of aperture 29	mm.
Length 64 mm.;	diam. 29	mm.;	length of aperture 29	mm.
Length 63 mm.;	diam. 31.5	mm.;	length of aperture 29	mm.
Length 62 mm.;	diam. 29.5	mm.;	length of aperture 28.5	mm.
Length 62 mm.;	diam. 29	mm.;	length of aperture 27.5	mm.
Length 61 mm.;	diam. 29	mm.;	length of aperture 27	mm.
Length 59 mm.;	diam. 27	mm.;	length of aperture 26	mm.
Length 56 mm.;	diam. 27.5	mm.;	length of aperture 26	mm.

On No-Name Key Hemphill in 1883 collected a number of small, light specimens of *graphicus*, one of which I have figured in the *Manual of Conchology*, XII, Pl. LIX, fig. 97. An adult specimen measures: Length 51 mm.; diameter 25.5 mm.; length of aperture 24 mm. These must have been from a different colony from that examined by us. We found only dead shells, chiefly inhabited by crabs, though part of them retain the color in all its freshness.

[20] *Pictus* was described originally as from "Cuba," and there are specimens in the collection of the Academy with that habitat on the labels, but with no record of the collector. I cannot learn that Poey, Gundlach, Wright, Arango or any other Cuban naturalist or collector ever encountered it there. I saw no *pictus* in the Havana collections, nor did I find it in my journey over half the length of the island, from the north to the south coasts, nor has it been taken by J. B. Henderson in several collecting journeys in Cuba. Orbigny figures a specimen of *pictus* in his Atlas of the *Mollusques* of Sagra's History of Cuba, plate VI, fig. 6; but he makes special mention of Floridan specimens in the text, and it is likely that this figure was drawn from one of these. Binney, in the *Terrestrial Mollusks*, vol. III, figures *pictus* on pl. LVI, lower and left-hand figures, and *solidulus* on pl. LV. On the whole I am disposed to believe that *pictus* is no Cuban snail, but like the other races of *solidus*, it is confined to the Florida Keys. The form *solidulus* resembles *solidus* superficially, and has been mistaken for it hitherto; but it is an albinistic variation of *pictus*. In one of the specimens, a very faint trace of dark pigment remains in one place upon the peripheral line. This is the only specimen at all intermediate in pattern I have seen in the entire *L. solidus* series.

Big Pine Key.

Length 69 mm.; diam. 29 mm.; length of aperture 29.5 mm.
Length 58 mm.; diam. 29 mm.; length of aperture 27 mm.
Length 58 mm.; diam. 28.5 mm.; length of aperture 26.5 mm. (*solidulus*).
Length 50 mm.; diam. 26 mm.; length of aperture 23.5 mm.

Average weight of seven specimens of this lot is .25 oz.

An adult but not old specimen, the only perfect one taken at Little Pine Key, measures: Length 48, diam. 23, aperture 20.5 mm. Others of the same lot did not differ much in size.

Specimens from Key West, Summerland Key and Boca Chica are all dead and none of them show traces of color-pattern. They appear to be like the shells of No-Name and Pine Keys. So far as the material goes, the same varicolored species appears to have extended over the Keys from Key West to No-Name Key. It is probably extinct now except on Big Pine and No-Name Keys. Unfortunately, the weather was very dry when Mr. Simpson and I were on the lower keys. The *Liguus* were in hiding, so that few specimens could be found. They must be sought in the rainy season.

The following material has been examined, exclusive of dead shells too old to show color or pattern.

	graphicus.	*solidus.*	*pictus.*	*solidulus.*
Key West		1[21]	..	..
Boca Chica	Long dead specimens only			
Summerland	Long dead specimens only			
Big Pine	10	..	1	2
No-Name	49	5	..	..
Little Pine	4	1	..	..

VIII. FIELD-NOTES OF MR. CLARENCE BLOOMFIELD MOORE RELATING TO THE DISTRIBUTION OF LIGUUS IN FLORIDA.

The localities mentioned are indicated on the map, Pl. XL, drawn by Dr. M. G. Miller.

Lee Co.

There is good evidence that *Liguus* formerly extended further north on the west coast than its present range. Mr. E. V. Stephens, postmaster of Marco and a dealer in shells, etc., states that eighteen or twenty years ago (about 1884–6) he found a few of them at Little Marco, and at Gordon's Pass. This pass is just south of Naples, a place on the mainland coast about fifteen miles north of Marco, by water.

Mr. J. W. Russell, of Russell's Key (where *Liguus* is found in abundance at the present time), who for two years has lived at Naples, after careful search and inquiry, reports that *Liguus* is not found at Naples at the present time (1904). Naples is in the same latitude as Fort Lauderdale, New River, where I found what I believed to be the northernmost specimens of *Liguus* on the east coast.

[21] Say's type of *L. solidus*. Other Key West specimens seen are too much weathered to show the pattern.

North of Naples, on Pine Island and on keys to the north and west of Pine Island careful inquiry has failed to locate any trace of *Liguus*, past or present. Reports of the presence of tree snails on Gasparilla Island, which is north of Pine Island, and on Sanibel Island, probably emanated from persons who confused *Liguus* with *Glandina* or with the snails found on the mangrove trees, *Littorina*. [The large *Littorina angulifera* often ascends six to ten feet or more, and is common on mangrove trees, piles, etc., all along the coast.]

At the present time (1904), it is believed that no *Liguus* is to be found at Little Marco. It was abundant at Marco, Key Marco, in former years, according to residents of Marco, but is not now to be found there. Search made on a nameless key which has good hammock vegetation, three miles east of Marco settlement, by Mr. Addison, the owner of the key, and living on it, failed to discover any trace of *Liguus*.

The northernmost habitat of *Liguus* on the west coast of Florida at the present time (1904) is believed to be Goodland Point, Island of Marco. This place is five miles south of Marco, which is a settlement at the northern end of the island of Marco.

Marco Island is the largest key of the Ten Thousand Islands, a region of islands ("keys") with open water here and there, beginning at Naples, about nine miles in a straight line north of the Island of Marco, and extending to the Northwest Cape, which is the upper end of Cape Sable.

Mr. Pettit, of Goodland Point, says *Liguus* is rapidly disappearing from Goodland Point (1906). A few were found by us there and no doubt more would be seen after rain. The women of the Pettit family now make baskets with snails arranged as pendants, each basket requiring thirty or forty snails. They have had snails brought from Miami and were offering to sell the shells, which were mixed with others from Goodland Point. The person who introduced this feature was not at the place when I procured the shells there two years ago. *Liguus* was found by us also at Caximbas, the southern end of Key Marco.

Horr's Island, south of Key Marco, at "Blue Hill," a hammock tract. No snails were found on the trees in 1904, though dead ones were on the ground. On February 14, 1907, a long search revealed a few living *Liguus*.

At Gomez's Old Place (a key), *Liguus* is fairly abundant.

At Cape Romano, Four Brothers Key, Dismal Key and Gomez Point Mr. House, who made a search for me, found no trace of *Liguus*.

Buttonwood Key, Lee County. But little suitable growth at this place. No *Liguus* seen on the trees or their shells on the ground in 1906.

Dismal Key, Lee County. Our agent was unable to find *Liguus* here in the summer of 1904. There is ample vegetation of a suitable character, but at our visit (March, 1906) we saw no sign of *Liguus* on trees or on the ground. An old woman and a little child live on this key. The old woman said that in the past she had seen tree snails on the key and described the coloring, showing she did not confound *Liguus* with the mangrove snails.

Fakahatchee Key. We found no *Liguus*, and the inhabitants of the key, who know the shells well, said they believed none to live on the island. There is abundant hammock apparently well fitted for these snails.

Russell Key. We obtained *Liguus* here in 1904 and also in March, 1906.

Wiggin's Key, Sandfly Pass. The inhabitants know *Liguus* and spoke of the shells as abundant at times. A bleached one was shown us. A long and careful search yielded none.

Turner Place or Key, Turner River. This is about one mile from Chokoloskee Key. *Liguus* was collected in 1904. In 1906 our visit was comparatively short, but considerable ground was covered by three persons. Only two *Liguus* were found high in gumbo limbo trees. It was explained that the frequent fires made to clear out the brush had destroyed most of the snails.

Chokoloskee Key.[22] *Liguus* in abundance in 1904. Most of the snails were well up in the trees. On revisiting the key in 1906 we found that much ground had been cleared since our last visit. Some *Liguus* are still to be seen on the trees. We bought a large number of shells from Mr. C. G. McKinney, among which were a few black ones. Although we collected a good many *Liguus* from the trees at Chokoloskee in 1906, and had boys procure for us many more from the trees with the living animal, none was of the black variety, like those obtained from Mr. McKinney.

MONROE CO.

Rabbit Key. A small outside key a few miles south of the pass leading to Chokoloskee Key. *Liguus* was found fairly numerous on the ground, but none was found alive after an exhaustive search. We were told that the northwestern part of the key, where we found the shells, was burned off about a year ago. Many shells lay on the ground, discolored by the flames.

Pavilion Key. *Liguus* does not occur on this key. *Oxystyla floridensis* is abundant on the trees.

Mormon Key (= "Harrison Key" on some maps). No snails found.

On Chatham River, which empties into the Gulf near Mormon Key, we found no snails for three miles up.

Snake Key. No snails; no shells on the ground.

Turkey Key. No snails; no shells on the ground.

Seminole Point. A key locally known as Plover Point. Many *Oxystyla* in a restricted space, but no *Liguus* seen.

A nameless key. No *Liguus;* no shells on the ground.

Porpoise Point (a key). No *Liguus;* no shells on the ground.

Lossman's Key, between Lossman's River and Rodgers R. In 1904 no snails were met with in a personal search of the high ground bordering this key, but a guide sent into the center of the key where a large amount of high ground is said to exist, brought back about fifty living *Liguus* which he found there.

[22] A recent survey has shown Chokoloskee Key to be in Lee Co. It appears on maps hitherto published in Monroe Co.

They are of a thin, white type, unlike any other West Florida lot [var. *lossmanicus*]. Subsequently we found several colonies.

This ends the Ten Thousand Islands. On the mainland at Cape Sable, Middle Cape, shells of *Liguus* were abundant on the ground, but living snails were rare on the trees. Mr. J. L. Watrous informed us that ten days before he had seen them abundantly. At East Cape the snails were found in considerable numbers here and there.

At Flamingo, still further eastward on the mainland, *Oxystyla* was found, but no *Liguus*. Neither occurred on Murray's Key, opposite Flamingo, about three miles out.

Sandy Key, to the south, has *Oxystyla* but no *Liguus*.

East of Flamingo, Monroe Co., no collecting was done by us on the mainland until we reached Cutler, on Biscayne Bay, Dade Co. The south coast of Dade Co. is said to be a mangrove shore. [Hammock land suitable for *Liguus* exists inland, colonies of *Liguus* being known from Homestead and Detroit.]

From Key Vaca northeastward the following keys have been investigated:

Lignum Vitæ Key. *Liguus* and *Drymæus* found.

Indian Key. Brush cleared off—no snails.

Lower Matecumbe Key, east end. The *Liguus* here were not sealed to the bark as at places visited heretofore.

West end Upper Matecumbe Key. *Liguus* scarce—a few met with.

Tea Table, a small key with unsuitable growth for snails—none found.

Windly's I, or Umbrella Key. *Liguus* found at the east end.

Long Island, or Plantation Key, west end. *Liguus* found.

Tavernier Key, a mangrove key unfit for snails.

Key Largo. In a hammock two miles east of the town of Planter *Liguus* was found, chiefly high in the trees. On Dove Key, opposite this place, there is no suitable vegetation. At Point Charles, Key Largo, *Liguus* was mostly high on trees and very firmly fastened. In a clearing where bushes were not high a few snails were found, large but paler than the rest as a rule, as if the sun had had a bleaching effect. I found at this place two snails of the kind found at Pavilion Key and Seminole Point (*Oxystyla floridensis*). Near the north end of Key Largo *Liguus* was also collected.

Pumpkin Key, inside the upper end of Key Largo. *Liguus* active.

Angel-Fish Key. Snails very scarce; only two found alive. Ten shells on the ground, one of these an extraordinarily large one.

Dade County.

Little Palo Alto Key. *Liguus* here are very frail, the shells often breaking from a slight fall.

Big Palo Alto Key. *Liguus* active.

A small, nameless key near Old Rhodes Key, has but little high ground; only small snails of another species.

Old Rhodes Key. At the north end *Liguus* was found. The living specimens are much smaller than many of the dead shells on the ground. The adjacent Reid's and Rubicon Keys are mangrove keys, hence without *Liguus*.

Totten's Key. *Liguus* living.

Porgy Key. Snails (*Liguus*) which began crawling in the rain of two days ago were mostly high in the trees here. Shells very frail. Many broke in falling.

Meiggs Key. Small, but with suitable vegetation. No living snails found, nor were any shells seen on the ground.

Cæsar's Rock, a small key with a little high ground. No sign of tree snails.

Adams Key. Large *Liguus* here and there on the ground, but only one live snail found in a search made by four persons.

Elliott's Key. A small pale form of *Liguus* was taken near the south end. No large ones were found, either alive or on the ground. A native of the key told us that snails of other colors are found there.[23]

Cape Florida, south end of Key Biscayne. The hammock has been cleared here recently and no vegetation suitable for *Liguus* was found by us. No live snails were met with, but small snail shells were abundant on the ground. A single *Liguus* of the Miami type was given us by the owner of the place, who said it came from there; but he may have been mistaken. On the remainder of Key Biscayne only mangrove is said to grow. No hammock land was visible from our boat.

No entirely trustworthy evidence of the existence of *Liguus* on the outer line of keys above Elliott's Key was obtained. That key is probably its northern outside limit.

The Arsenicker Keys—small inside keys near the mainland—are mangrove keys without suitable vegetation for *Liguus*.

Mainland of the East Coast, Dade Co.

Cutler, Dade Co. *Liguus* abundant. The winter of 1903–4 has been the dryest season in years, but during our visit there was rain. The *Liguus* appeared on every side, many were on bushes or piles of brush, as if they had been hidden in damp places on the ground. The shells marked with brown are chiefly found in the thick woods.

Miami, at the mouth of the Miami River. *Liguus* is abundant in the woods on the south side of the river, opposite the town. Also on the north side of the river, about 2½ miles west. Opposite this place it occurs on the south side as well.

At the House of Refuge, on the outside near the head of Biscayne Bay, no suitable hammock land exists, and *Liguus* is not found.

At Natural Bridge, on Arch Creek, about 9 miles north of Miami, *Liguus* was found to be scarce, only four living ones found, though the hammock is extensive and apparently favorable.

[23] It is quite possible, however, that he had in mind the variegated forms he may have seen at Miami, Cutler, Largo or elsewhere, or even snails of some other genus. H. A. P.

After entering the canal at the head of Biscayne Bay hammock land is scarcely met with. There is the scrub growth of the beach, mangroves along the canal, pines farther in and then probably the everglades.

Fort Lauderdale, New River, about 24 miles (as the crow flies) north of Miami. There is hammock on both sides of the river about a mile below the town. *Liguus* was found but not abundant, and only the white, green-lined variety. This is apparently the northern limit of *Liguus* on the east coast of Florida.

North of this we made inquiry of the inhabitants along the canal, where hammock land was in sight, but in no case had *Liguus* been seen by them.

Around the southern end of Lake Worth there is much fine hammock, where the vegetation seemed to be perfectly adapted to *Liguus*, but a careful search by my party yielded no evidence of their presence there, either in the trees or on the ground. *Glandina*, etc., are numerous. At Palm Beach a dealer in shells told me he had sold many of the *Liguus* from Miami, but had found none around Lake Worth. A number of living ones from Miami which he had liberated in the hammock at Lake Worth did not survive.

[Mr. Moore was repeatedly told of a "blue snail" to be found in hammocks on the lower keys, especially on Pine Key; but although special search and inquiry was made on every key visited by Mr. Raybon, Messrs. Brown and Fowler, and by Mr. Simpson and myself, none was found. The only "blue" snail to be found was *Janthina*, which is sometimes carried there by a hermit crab which has a large violet claw of the same tint as the shell. As this crab is common in the hammocks, it seems likely that the widespread tradition of a "blue snail" may refer to *Janthina*.]

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11

11A

11B

12

12A

13

12B

14

14A

14B

14C

14D

14E

15

16

16A

16B

16C

16D

17

17A

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18A

19

19A

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PILSBRY: VARIATION AND ZOOGEOGRAPHY OF LIGUUS.

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PLATE XL.

Map of southern Florida showing known localities of *Liguus* and *Oxystyla*. Drawn by Dr. M. G. Miller.

PILSBRY: VARIATION AND ZOOGEOGRAPHY OF LIGUUS

Analyse der Süd-Amerikanischen Heliceen

VON

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PLATES XLI–XLII

PHILADELPHIA

1912

ANALYSE DER SÜD-AMERIKANISCHEN HELICEEN.

Von Dr. Hermann von Ihering.

Im Jahre 1892 versuchte ich durch eine Arbeit (op.[1] 118) über den Genitalapparat der Heliciden die Systematik der Familie auf natürlicher Grundlage auszuarbeiten. Pilsbry hat in seinem grossangelegten, überaus wertvollen *Manual of Conchology*, Vol. IX, diese Bestrebung bedeutend gefördert und ich selbst habe dann 1909 (op. 256)[2] auf Grund meiner Untersuchungen die Classification der Heliciden im Interesse der Geschichte und geographischen Verbreitung dieser Landschnecken aufs Neue behandelt, und weitere Studien mit Rücksicht auf die verschiedenen Elemente der Pulmonaten, welche die neotropische Region zusammensetzen, in Aussicht gestellt. Pilsbry hat im vorigen Jahre im Werke der Princeton Expedition dieses Thema eingehend erörtert. Wenn auch unsere Auffassung in vielen Punkten sich deckt, so fehlt es doch auch nicht an Widersprüchen, wie besonders in Bezug auf *Strophocheilus* und die Bulimuliden. Ich komme daher um so lieber der Erfüllung der früher gemachten Zusage nach, als es mir, von einer einzigen Gattung abgesehen, gelungen ist, Tiere aller noch fraglichen südamerikanischen Vertreter der Gruppe zur anatomischen Untersuchung zu erhalten.

Pilsbry, der früher weder von antarktischen Beziehungen noch von einer süd-atlantischen Brücke etwas wissen wollte, stimmt jetzt meiner Auffassung bei und hat andererseits mich gezwungen, die Annahme einer, Central-Amerika mit den Sandwich-Inseln verbindenden Landbrücke, meiner "Pacila," fallen zu lassen. Irre ich nicht, so werden diese Studien über die Geschichte der Landschnecken bald dahin führen, die paläogeographischen Wandlungen der Erde in ihren allgemeinen Zügen klar zu legen.

Eine Entdeckung, welche ich während der Ausarbeitung dieser Abhandlung machte, erscheint mir so bedeutsam, dass ich sie hier aufgenommen habe, obwohl sie eine andere Ordnung der Mollusken betrifft. Es ist der Fund einer obercretazeischen oder untereocänen Art von *Pleiodon* in S. Paulo. Bisher kannte man lebende Vertreter von Muteliden[2] mit taxodontem Schlosse nur aus Inner-

[1] Bibliographia dos trabalhos do Dr. H. v. Ihering, Notas e preliminares do Museu Paulista, vol. 1, fasc. 2, S. Paulo, 1911. Morphologie u. Systematik des Genitalapparates von Helix, *Zeitschrift für wissensch. Zoologie*, Bd. LIV.

[2] System u. Verbreitung der Heliciden, *Verh. der k. k. zool. bot. Ges.*, Wien, 1909, p. 420–455.

[3] Ich behalte die Familie der Muteliden so bei, wie ich sie definiert habe. Die Anatomie bietet zur Scheidung der Muteliden und Unioniden nicht die nötigen Anhaltspunkte; das zeigt das Ergebnis von Ortmann's bezüglichen Studien, in denen er Muteliden und Hyriinen in eine Familie zu vereinen vorschlägt. Nach Schale und Entwicklung bilden die Mutelidae Ih. eine natürliche, gute Familie, und ich zweifle nicht, dass die noch ausstehende, morphologische Untersuchung der afrikanischen Muteliden mir recht geben wird.

Afrika, fossile noch gar nicht. *Pleiodon priscus* von S. Paulo ändert die Lage. Pilsbry war noch geneigt, die Muteliden und andere afrikanische Binnen-Mollusken von Afrika aus nach Brasilien durch Wanderung gelangen zu lassen. Die neue Entdeckung macht diese Vermutung gegenstandslos und zwingt uns anzuerkennen, dass in dem weiten Gebiete der Archhelenis ursprünglich eine mehr oder minder einheitliche Fauna existierte, in welcher dann allmählich sich zoogeographische Provinzen ausbildeten und zwar vermutlich schon vor der teilweisen Unterbrechung der transatlantischen Brücke.

Aufgabe unserer analytischen Forschung ist es, nicht nur die verschienen faunistischen Elemente zu erkennen, aus deren Mischung die neotropische Tierwelt ursprünglich hervorging, sondern auch den weiteren Zuwachs, welchen tertiäre Wanderungen aus anderen Erdteilen hinzufügten. Als ein Beitrag in diesem Sinn wollen die folgenden Untersuchungen gelten, in welchen ich erst neue zoologische und anatomische Beschreibungen mitteile und dann die zoogeographischen Schlussfolgerungen, zu denen dieselben berechtigen, anschliesse.

Es ist sonderbar, wie verschieden die Urteile der Fachgenossen sich gestalten, je nachdem Land- und Süsswasser-Mollusken oder Säugetiere die Grundlage der Erörterung bilden. Während ich mit Eigenmann, Ortmann, Pilsbry u. a. in Bezug auf die Archhelenis im Wesentlichen übereinstimme, ist das weder mit H. F. Osborn noch mit Fl. Ameghino der Fall, welche beide Afrika als ein wichtiges Entwicklungs-Centrum der tertiären Säugetiere ansehen. So sehr Osborn's grossartiges Werk, *The Age of Mammals*, meine Bewunderung erregt, so wenig kann ich das für richtig halten, was er, den Wallace'schen Standpunkt im Wesentlichen festhaltend, über die Säugetiere von Afrika sagt. Schon das ist ein Irrtum, die mediterrane Zone von Afrika, welche im Tertiär wie in der Gegenwart zum eurasischen Gebiet gehört hat, der aethiopischen Region zuzurechnen. Das ganze Gebiet der Archhelenis hat im älteren Tertiär gar keine Säugetiere besessen, kann daher auch kein Centrum adaptiver Irradiation gewesen sein. Die ältere Tertiär-fauna von Asien wird den Schlüssel zum Verständnisse der Cairo-Fayum-Säugetiere liefern. Von jener aus hat Madagascar seine Lemuriden, *Hippopotamus*, etc. erhalten, aber die pliocäne Einwanderung von Säugetieren, die sich über Arabien in breitem Strome nach Afrika ergoss und die Giraffen, Gazellen, Löwen, etc. dahin brachte und gleichzeitig auch die Cypriniden und andere nördliche Elemente der Süsswasser-Fauna, haben den Weg nach Madagascar schon abgebrochen gefunden.

Es gibt keine Elemente der patagonischen Säugetierfauna im tertiären Afrika und nur die marinen Säugetiere machen davon scheinbar eine Ausnahme, insofern von den in der Nordhemisphäre entstandenen Sirenien (Jamaica, Aegypten) eine Gattung den Nordrand der Archhelenis erreicht hat. Das Vorkommen von lebenden Arten der Gattung *Manatus* in West-Afrika und Brasilien kann nur durch die Archhelenis-Theorie verständlich gemacht werden, zumal wenn man das Vorkommen fossiler Vertreter derselben in neogenen Ablagerungen von Nord-Argentinien (*Ribodon*) und der Insel St. Helena mit in Betracht zieht. Es ist

bedauerlich, dass Osborn weder mein Archhelenis-Buch (op. 246), noch mein Werk über die Tertiär-Conchylien von Argentinien (op. 248), beide von 1907, kennen gelernt hat. Die neueren Untersuchungen von Prof. Stromer zwingen mich, die Nordgrenze der Archhelenis mehr aequatorwärts zu schieben und auf Pilsbry's Einspruch hin habe ich die "Pacila" fallen lassen.

Ameghino's Ansicht, dass bis in das Pliocän eine Senegal-Guiana-Brücke der Wanderung der Säugetiere gedient habe, findet weder in der Geschichte der Säugetiere selbst eine haltbare Stütze, noch vor allem ist sie mit der Geschichte der litoralen Mollusken Süd-Amerikas vereinbar, wie sie durch mich im Buche über die Tertiär-Conchylien Argentiniens festgestellt wurde. Ich habe zuerst bezüglich der Säugetiere nachgewiesen, dass die Wanderung von Formen der nördlichen Hemisphäre nach Süd-Amerika sich auf zwei verschiedenen Wegen vollzog; darin hat mir Ameghino beigepflichtet, aber für die ältere Wanderung eine andere Route ins Auge gefasst. Bären und Subursen sind eher nach Argentinien gekommen als nach Nord-Amerika. Die vermeintlichen Procyoniden Nord-Amerikas sind mit *Bassariscus* verwandt, und werden von mir den Caniden, von Stromer den Viverriden zugerechnet. Unter diesen Umständen kann ich nur an der von mir früher gegebenen zoogeographischen Entwicklungsgeschichte Süd-Amerikas fest halten, und die Hoffnung aussprechen, dass mein Archhelenis-Buch und das Werk über die Tertiär-Conchylien Argentiniens in Nord-Amerika mehr Verbreitung und Lectüre finden. Mit dem Anachronismus der Widerholung Wallace'scher Darstellungen wird es dann wohl ein Ende nehmen. Wichtiger als die Säugetiere sind für die Erforschung der Paläogeographie die Landmollusken, nicht nur als Dauertypen von erheblichem Alter, sondern auch deshalb, weil sie schwerfälliger in ihrer Ausbreitung und Anpassung sind. So haben Katzen, Stinktiere, Marder, Pferde, *Mastodon* u. s. w. von Nord-Amerika aus sich nach Süd-Amerika verbreitet, und umgekehrt, Arten von *Didelphis*, *Tatu* u. a. m. Nord-Amerika invadiert; aber keine einzige Landschnecke hat sich an diesen Wanderungen beteiligt. Die aus beiden Tiergruppen gewonnenen Ergebnisse decken sich nicht, aber sie stehen auch nicht im Mindesten im Widerspruch miteinander.

A. Zoologisch-anatomische Beobachtungen.

Fam. HELICIDÆ.

Auf diese Familie gehe ich hier nicht näher ein, da ich erst kürzlich den Gegenstand eingehend behandelt habe.[1] Die Differenzen, welche in einigen Punkten zwischen Pilsbry und mir bestehen, sind für die hier erörterten Fragen bedeutungslos. Pilsbry[2] macht mich darauf aufmerksam, dass doch hinreichend Gründe vorhanden seien, den amerikanischen *Arionta*, die ich nur als Untergattung *Epiphragmophora* gelten liess, den Rang einer Gattung zuzusprechen,

[1] H. von Ihering, System und Verbreitung der Heliciden. Mit einer Karte, 20. Dez., 1908. In *Verhandlungen der k. k. zoologisch-botanischen Gesellschaft in Wien* (Jahrgang 1909).

[2] H. A. Pilsbry, Non-marine Mollusca of Patagonia, *Reports of the Princeton University Expeditions to Patagonia*, 1896–1899, vol. V, Stuttgart, 1911, p. 622.

und indem ich mich Pilsbry's Ansicht hiermit anschliesse, möchte ich damit besonders der grossen Erfahrung, welche er durch langjährige Arbeit in der Abgrenzung der systematischen Gruppen gewonnen hat, meine Anerkennung zollen. In der Hauptsache, dass nämlich die amerikanischen Heliciden dem eurasischen Faunengebiete entstammen und durch eine frühtertiäre Wanderung nach Zentral-Amerika gelangten, sind wir ganz gleicher Meinung.

Fam. PLEURODONTIDÆ.

SOLAROPSIS.

Taf. XLI, fig. 1–4.

Die systematische Stellung dieser Gattung blieb zweifelhaft bis zum Jahre 1900, in welchem meine diesbezüglichen Abhandlungen,[1] welche die Anatomie von *S. feisthameli* behandelt, erschien. Im gleichen Jahre, wenige Monate später, veröffentlichte Fr. Wiegmann[2] eine bezügliche Studie, welcher Tiere von *S. heliaca* Orb. zu Grunde lagen. Es war Wiegmann entgangen, dass an dem von ihm untersuchten grössten Tiere der männliche Teil des Geschlechts-Apparates noch ganz unentwickelt war; ich habe daher den Gegenstand 1902 nochmals besprochen.[3] Alle anderen, diese Gattung betreffenden Verhältnisse findet man in Pilsbry's *Manual*.[4] Einzig die anatomische Angabe bei Pilsbry, dass der Kiefer glatt sei, ist irrig; er bezieht sich dabei auf eine offenbar durch ein Versehen gemachte Angabe von E. von Martens.

Was mich veranlasst, jetzt auf den Gegenstand zurückzukommen, ist die Untersuchung einer weiteren, bisher dem Tiere nach nicht bekannten Art, *Sol. braziliana* Desh. Ich werde zunächst meine bezüglichen Beobachtungen mitteilen, um dann auf die Verwandtschafts-Beziehungen der Gattung zurückzukommen.

Für *Sol. feisthameli* Hupé kann ich die früheren Beobachtungen in einigen Punkten erweitern. Über den Fuss läuft in der Mitte eine Längsfurche; der linke Mantellappen fehlt, der rechte ist klein, neben dem Atemloch gelegen. Die Niere ist von langgestreckter Form, nach vornhin verschmälert (Taf. XLI. fig. 1).

Nahe ihrem hinterem Ende liegt das 9 mm. lange Pericardium; die Niere selbst ist 31 mm. lang bei 5 mm. Breite. Am Genitalapparat (Taf. XLI, fig. 2) wurden die früheren Beobachtungen bestätigt; der Retractor des männlichen Genitalapparates tritt nicht an den Penis, sondern an den, nach Art eines flagellum von ihm abgetrennten Epiphallus. Die Hauptmasse des Muskels inseriert sich am freien Ende des Epiphallus, einige Fasern verlaufen nach unten zu seiner Insertions-

[1] H. von Ihering, Os caracoes do genero *Solaropsis*, *Revista do Museu Paulista*, vol. IV, 1900, p. 539–49 (28. Juli, 1900).

[2] Fr. Wiegmann, Anatomische Untersuchung von *Solaropsis*, *Nachrichtsblatt der deutschen malak. Gesellschaft*, Bd. 32, 1900, p. 178–184.

[3] H. von Ihering, Zur Systematik der Gattung *Solaropsis*. *Nachrichtsblatt der deutschen malak. Gesellschaft*, Bd. 34, 1902, p. 179–180.

[4] Henry A. Pilsbry, *Manual of Conchology, Pulmonata*, vol. 9, Philadelphia, 1894, p. 166 ff.

stelle am Penis. In der Mitte des Blasengangs entspringt ein kurzes, aber dickes Divertikel. Im Uterus wurden zwei Eier von 7.5 mm. Durchmesser gefunden; ihre Schale ist dünn, 0.15–0.2 mm. dick, kalkig, fein gerunzelt.

Von *Solaropsis braziliana* Desh. konnte ich ein guterhaltenes Exemplar aus dem Staate São Paulo untersuchen. Das Tier unterscheidet sich nicht wesentlich von dem der vorigen Art. Die schmale Niere hat eine Länge von 22 mm., der Herzbeutel ist 8.5 mm. lang, der Abstand der Niere vom Atemloch beträgt 22 mm. Hiernach ist die etwas unklare Beschreibung bei Wiegmann zu berichten, derzufolge die lange Niere bis nahe zum Atemloche sich hin ziehen würde. Im Allgemeinen ist mithin bei den *Solaropsis*-Arten die Niere dreimal so lang als der Herzbeutel. Der Kiefer von *Solaropsis brasiliana* ist stark und mit 26 bis 28 kräftigen, etwas ungleichen Rippen verziert, welche bald dicht aneinander stehen, bald durch einen etwas grösseren Zwischenraum getrennt sind. Die Zähne stehen auf der Radula in 66–1–66 Längs-Reihen. Der Mittelzahn ist einfach, fast ohne Schneide. Die ersten 30 Seitenzähne sind einspitzig (Taf. XLI, fig. 3*a*), bei den folgenden erscheint ein kurzer Ectocon (Taf. XLI, fig. 3*b*). Der Mesocon ist nur an der Mittelplatte rudimentär, gewinnt dann eine ziemlich bedeutende Länge, sodass er um ein Drittel über die Platte vorstecht, um dann an den Randzähnen wieder kürzer zu werden. Am Genitalapparat (Taf. XLI, fig. 4) ist im Verhältnis zu der vorigen Art die Lage des Divertikels am Receptaculum seminis auffallend, da dasselbe sehr lange ist und an der Basis des Ganges einmündet. Das Flagellum entspringt an der Einmündung des Vas deferens in den Epiphallus und ist in seiner Mitte sackförmig verdickt. Der Epiphallus setzt sich unmittelbar in den kurzen, nahe dem Orificium gelegenem Penis fort und hat mit ihm nahezu die gleiche Dicke. Der Retractor spaltet sich in zwei Äste, von denen der stärkere sich an den mittleren Teil des Epiphallus inseriert, während der zweite, schmälere Schenkel zum Penis hinzieht.

Meine hiermit vermutlich zum Abschluss gelangten Studien über die Anatomie der Gattung *Solaropsis*, bestätigen die früher gewonnenen Erfahrungen und weisen ihr ihren Platz neben *Chloritis*, *Pleurodonte* u. a. Gattungen der *Epiphallogona* Pilsbry's an, welche jetzt die Familie der *Pleurodontidæ* bilden. Schon die Schale lässt für *Solaropsis* und *Psadara* nahe Beziehungen zu *Chloritis* und *Planispira* vermuten und es ist bemerkenswert, dass das Tier von *Solaropsis* eine mediane Längsfurche des Fussrückens hat wie *Chloritis*. Wichtiger als diese äusseren Merkmale sind die inneren, unter denen die schmale, längsgestreckte Form der Niere allen Gliedern der Familie gemein ist und sie scharf von den Acaviden und Heliciden scheidet. Wiegmann und Pilsbry haben mit Recht diese Eigentümlichkeit als wichtig betont. Ein weiteres, characteristisches Merkmal der Familie ist die eigentümliche Ausbildung des mit Epiphallus und Flagellum ausgerüsteten männlichen Apparates. Gerade hierin aber hat uns die Untersuchung von *Solaropsis* erhebliche Differenzen erwiesen. *Solaropsis heliaca*, über die wir nur unvollkommen unterrichtet sind, scheint sich im Wesentlichen an *S. brasiliana* anzuschliessen, wenigstens entspringt bei beiden das

Divertikel des Blasenstieles am Grunde dieses Ganges. Bei *S. feisthameli* dagegen inseriert sich das Divertikel hoch oben am Gange des Receptaculum seminis. Ein solches Divertikel kommt im Allgemeinen bei Pleurodontiden nicht vor; aber es ist doch sehr wahrscheinlich, dass bei Ausdehnung der Untersuchung auf zahlreiche Arten von *Chloritis*, etc. dasselbe auch bei asiatischen Vertretern der Familie gefunden werden wird. In diesem Sinne verstehe ich z. B. die Zeichnung des Genitalapparates der *Chloritis dinodeomorpha* von Tapparone-Canefri, wo an der Basis des Ganges der Samentasche ein im Text nicht erwähntes, schlauchförmiges Divertikel zu sehen ist.

Wie sehr selbst innerhalb einer Gattung gewisse anatomische Verhältnisse variieren können, zeigt eben wieder das Beispiel von *Solaropsis*. Das Divertikel des Blasenganges mündet an der Basis des Ganges bei *S. heliaca* und *braziliana*, in seiner Mitte bei *S. feisthameli* und der Retractor des Penis inseriert sich an den Epiphallus bei *S. feisthameli*, an den Penis bei *S. braziliana*. Pilsbry war noch der Meinung, dass erstere Form der Insertion allen altweltlichen Vertretern der Familie zukomme. Jetzt haben wir diese Differenzen innerhalb eine natürliche Gattung Brasiliens. Scheinbar sehr auffällig und unerklärlich ist der Umstand, dass der Retractor sich bald an den Penis, bald an den Epiphallus inseriert und dass letzterer bald in der Continuität des vom Vas deferens und Penis gebildeten Rohres liegt, bald wie bei *Solaropsis feisthameli* als Divertikel sich presentiert. Ihre Erklärung finden diese Verhältnisse in der Lageverschiebung der Penispapille und deren geringeren oder grösseren Abtrennung von seiner als Epiphallus bekannten Verlängerung. Im Zusammenhange damit steht es, dass der Retractor in seinem Endteil bei *Solaropsis* gespalten ist; von diesen beiden Zweigen wird bei *S. brasiliana* der untere als Penis-, der obere als Epiphallus-Ast zu deuten sein.

Ähnlich steht es mit dem Kiefer, der bei den Pleurodontiden mit starken Rippen besetzt ist, deren Zahl aber zuweilen sehr gering ist, und auf 2 oder 0 zurückgeht, sodass im letzterem Falle ein sekundär glatt gewordener Kiefer vorliegt, wie bei *Pleurodonte*, wo derselbe bald in der Mitte noch mit Rippen versehen, bald ganz glatt ist. An der Radula haben *Solaropsis heliaca* und *Psadara derbyi* den Mittelzahn dreispitzig, bei den anderen *Solaropsis*-Arten sind diese Zähne einspitzig.

Alle diese Verhältnisse, deren Bedeutung und Umfang bei Ausdehnung der Forschung sich naturgemäss noch erhöhen werden, erschweren die Fixierung der Familien- und Gattungscharaktere; aber sie haben uns darum keineswegs dazugeführt, an der von Pilsbry und mir durchgeführten Classification der Heliceen irre zu werden. Wir dürfen vielmehr die Pleurodontiden als eine gut begründete Familie ansehen, deren Heimat in Eurasien lag, deren Vertreter im älteren Tertiär von Europa zu finden sind, die niemals Afrika und Madagaskar, aber im Tertiär auch Centralamerika und Westindien von Ostasien aus erreichten, von wo aus sie dann neogen nach Süd-Amerika gelangten.

Familie ACAVIDÆ.

Macrocyclis laxata (Fér.) Taf. XLI, fig. 5, 6.

Von dieser hübschen und wohlbekannten Art von Südchile erhielt ich durch die Güte des Herrn Carlos Bruch vom La Plata Museum zwei Exemplare mit Tier, welche Herr Dr. Wolfshügel ungefähr in der Höhe des Nahuel-Huapi-Sees sammelte. Die Schale hat einen grössten Durchmesser von 64 mm., gehört demnach zur Varietät *banksi* Cuming. Das Tier ist von schwarzer, etwas ins blaue gehender Farbe. Die Fusssohle ist einfach, ohne abgesetzten Rand. Von den Lappen des Mantelrandes ist der grössere rechte von einförmiger Gestalt, der linke weniger ausgebildet. Die Niere ist dreieckig, wenig umfangreich, der Herzbeutel entspricht in seiner Grösse ungefähr zwei Drittel derjenigen der Niere. Der Kiefer ist schmal und misst 5.3 mm. in der Breite und 0.8 mm. in der Höhe; er ist glatt, mit zahlreichen feinen Längsstreifen. Die Radula hat mehr oder weniger gleichförmige, lange einspitzige Zähne (Taf. XLI, fig. 5, *a–c*) in der Zahl von 54–56 auf jeder Seite. Der Genital-Apparat (fig. 6) ist einfach; von der Scheide geht die Samentasche aus, gross, mehr oder weniger zylindrisch und fast ohne Endanschwellung. Am Endpunkt bemerkt man einen kleinen Kanal, der mit dem Uterus in Verbindung steht. Wahrscheinlich bildet dieser Kanal den Rest des alten receptaculo-uterinen Vorbindungsganges, aber eine Reihe von mikroskopischen Querschnitten konnte keinerlei Zusammenhang mit dem Receptaculum nachweisen. Doch bestand vermutlich im Anfang der Embryonal-Entwicklung diese Verbindung. Der Penis ist einfach, mit 10–12 Längsfalten und verlängert sich über die Einfügung des Musculus retractor, der am Ende des Penis sich ansetzt, zu einem kurzen, aber dicken Epiphallus, welcher die Fortsetzung des Vas deferens ist.

Bis jetzt war die Anatomie von *Macrocyclis* unbekannt. Pilsbry: *Manual of Conchology, Pulmonata*, vol. 9, 1894, p. 165, beschreibt die Radula unserer Art; aber die Figuren passen wenig zu den meinen und die Zahl der Zähne—33–1–33—ist so verschieden von der von mir beobachteten 56–1–56, dass aller Wahrscheinlichkeit nach irgend ein Fehler in der Klassifizierung des untersuchten Tieres unterlaufen ist. Noch weniger glücklich war Wiegmann: *Nachrichtsblatt der deutschen malakozoologischen Gesellschaft*, Jahrgang 22, 1900, p. 183, der vom Genitalapparat der *Macrocyclis laxata* sagt, dass an der Basis des Receptaculum-seminis sich ein Divertikel befindet. Dies ist nach den zwei grossen, von mir untersuchten Exemplaren falsch. Die verwandten australischen Arten (*Pedinogyra*) sind alle mit einer solchen Appendicula versehen, weshalb der Schluss naheliegt, dass das von Wiegmann untersuchte Tier aus Australien stammte.

Die systematische Stellung des Genus *Macrocyclis* ist, wie bereits Pilsbry annahm, in der Gruppe der Macroögona, worin *Macrocyclis* der einzige helicoide amerikanische Vertreter ist. Die genannte Gruppe teilt sich in zwei Sektionen, die eine mit Appendicula an der Basis des Receptaculum seminis, die andere ohne derartigen Anhang. Die Gattung *Panda* und drei weitersnächstverwandte

Gattungen von Australien und Tasmanien sind mit dieser Appendicula versehen, welche den vier Gattungen der zweiten Gruppe fehlt, nämlich den Gattungen *Macrocyclis* von Chili, *Ampelita* und *Helicophanta* von Madagaskar und *Acavus* von Ceylon. Alle diese Gattungen haben einspitzige Radulazähne, einen glatten, einfachen Kiefer, eine kurze, dreieckige Niere und einen einfachen Genitalapparat ohne Flagellum des Penis oder Liebespfeil der Vagina. Das Embryonalgewinde ist, wie Pilsbry richtig bemerkt, gross und entspricht einem Drittel bis Siebentel des grössten Schalendurchmessers.

Die grösste Schale, die ich von *Macrocyclis laxata* besitze, misst in ihrem grössten Durchmesser 64.5 mm. ohne Lippe, mit ihr aber 68.2 mm. Sie hat 5½ Umgänge, deren drei dem Embryonalteil angehören, dessen Durchmesser von 10.5 mm., einem Sechstel des grössten Durchmessers der Schale entspricht.

STROPHOCHEILUS Spix.

Pilsbry hat Recht, wenn er diese Gattung den Acaviden zugestellt. Wenn Zweifel in dieser Hinsicht noch blieben, so war es vor allem wegen der Dürftigkeit der bisherigen, anatomischen Kenntnisse. Sogar dieses Wenige, was bisher bekannt war, ist zum Teil falsch. So bezieht sich die Beschreibung des Genitalapparates von *Str. oblongus*, die Semper im Philippinen Werke (p. 150, Taf. 14 fig. 10; Taf. 16, fig. 25; Taf. 17, fig. 1) veröffentlichte, nicht auf diese Art, sondern auf eine der Schale nach ähnliche, vermutlich *Str. ovatus* Müll. Eine zutreffende Darstellung gab ich selbst früher (*Bull. scient. de la France et de la Belgique*, vol. 22, 1891, p. 213, Pl. V, fig. 11). Im Allgemeinem verweise ich hier bezüglich der Literatur auf Pilsbry's Darstellung in seinem *Manual of Conchology, Pulmonata*, vol. 10, 1896. Mir lag nun vor allem daran, zu wissen, wie weit die bei *Str. oblongus* gewonnenen Erfahrungen verallgemeinert werden dürfen. Ich habe daher das mir zugängliche, reiche Material aufs Neue untersucht.

Von der Untergattung *Thaumastus* lag mir *Str. achilles* Pfr. vor. Diese Art hat einen 4 mm. breiten Kiefer mit 12 breiten, regelmässigen Leisten, durch welche der freie Rand dentikuliert wird. Der Genital-Apparat ist einfach, ohne Anhangs-Organe. Die Vagina ist dünnwandig, aber von einer dicken Lage concentrischer Muskelscheiden umgeben. Das Lumen des Penis ist im hinteren, epiphalloiden Teil vierkantig, in der Mitte mit 6 Leisten versehen; weiterhin gegen die Mündung verlieren sich dieselben.

Im Receptaculum seminis fanden sich zwei Capreoli vor. Dieses chitinöse Gebilde ist 10–12 mm. lang, in der Mitte 1.8 mm. dick, am Ende der einen Seite vierkantig, am anderen cylindrisch. Im Zentrum befindet sich eine angeschwollene Partie, welche die Samenmasse enthält; das Weitere ergibt sich aus unserer Abbildung, Taf. XLI, fig. 7. Capreoli ähnlicher Art kenne ich auch von anderen Arten von *Strophocheilus*. Bemerkt sei noch, dass in der Lungenwand sich zahlreiche, eingekapselte Nematoden-Larven befinden, wie mir schien, nicht von jenen der grossen *Borus*-Arten verschieden.

Von der Untergattung *Strophocheilus s. str.* untersuchte ich *Str. unidentatus*

Sow. und *Str. pilsbryi* Ih. Der Genitalapparat ist einfach, ohne Divertikel am Gang des Receptaculum seminis und ohne Flagellum am Penis. Der Retractor setzt sich an den mittleren Teil des starken, gewundenen, zumal nach unten verdickten Penis an, so dass doch wohl der zwischen Vas deferens und Retractor-insertion gelegene Teil des Penis als Epiphallus zu deuten sein wird. Der Kiefer war kräftig, 3.8 mm. lang bei 1.5 mm. Höhe, fein rugulös und gestrichelt sowie mit einzelnen, wellig erhobenen, niederen breiten Leisten versehen, die als Zahnleisten gedeutet werden können.

Von der Untergattung *Borus* lag mir ein reiches Material vor, aber die Verhältnisse sind sehr uniform. Der Genital-apparat gleicht jenem der oben beschriebenen Arten und nur bei wenigen Arten hat die überall sehr dickwandige Vagina eine eigenartige Umbildung erfahren. Einen einfachen Genitalapparat fand ich unter anderen bei *Str. ovatus* Müll., *martensi* Pils., *cantagallanus* Rang, *auritus* Sow. Den zweiten Typus vertritt *Str. oblongus* Müll. von mir, wie oben angegeben, beschrieben. Bemerkenswert ist der Befund eines dick muskulösen Sackes, einer Appendicula der Vagina, welche an der Einmündungsstelle des Ganges des Receptaculum seminis gelegen ist. (Taf. XLI, fig. 8.) Eben so liegen die Verhältnisse bei *Str. sanctipauli* Ih. und Pils., welcher mit *Str. oblongus* nächst verwandt ist, vielleicht nur Subspecies dazu. Die einzige weitere Art, wo ein ähnliches Verhältnis angetroffen wurde, ist *Str. granulosus* Rang (Taf. XLI, fig. 9). Der dünnwandige Uterus wird an seinem distalen Ende dickwandig, muskulös und mündet in einen ovalen, dickwandigen Sack, die Vagina, ein, an deren oberem Ende eine ebenfalls dickwandige, durch eine muskulöse Scheide verstärkte, Appendicula ansitzt. Der Gang des Receptaculum seminis mündet am unteren Ende der Vagina, nahe ihrer Ausmündung. Diese Verhälnisse stimmen im Allgemeinem mit jenen bei *Str. oblongus* überein, nur ist die blasige Auftreibung der enorm dicken Vagina eine viel bedeutendere.

Es ist wichtig, bei der Characterisierung der Gattung *Strophocheilus* von *Str. oblongus* und den nahestehenden, grossen Arten abzusehen, da sie mancherlei Absonderliches darbieten. Dies bezieht sich nicht nur auf die Appendicula der Vagina, sondern auch auf den gelappten Fortsatz neben den Munde, welcher den meisten Arten der Untergattung *Borus* und allen Vertretern der übrigen Subgenera fehlt. Sehen wir daher von den speciellen Verhältnissen bei einigen Arten der Untergattung *Borus* ab, so liegt kein Grund vor, *Strophocheilus* von den übrigen Acaviden abzutrennen. Pilsbry's Darstellung der Anatomie dieser Gattung ist hiernach zu modifiziren.

Familie BULIMULIDÆ.

TOMIGERUS Spix.

Taf. XLII, fig. 24, 25.

Über diese Gattung habe ich in den *Proceedings of the Malacological Soc.* London, vol. VI, 1905, p. 197–199 eine Mitteilung gemacht, welche in derselben *Proceedings*, vol. VII, 1906, p. 68 dahin ergänzt wurde, dass der Name des Sub-

genus *Pilsbryella* Ih. (nec Nierstrass) durch *Cearella* Ih. 1906 ersetzt wurde. Es war mir damals nicht möglich, die Anatomie der Gattung zu untersuchen, eine Lücke, die ich dank der Güte des Herrn Francisco Dias da Rocha 1910 ausfüllen konnte. Das Resultat der Untersuchung teilte ich damals Herrn Pilsbry brieflich mit, wobei ich ihm zugleich die Mundwerkzeuge des untersuchten Tieres in einem Gläschen mit Alkohol zusandte. Er hat Taf. XLII, fig. 24 und 25 gezeichnet. Der Mittelzahn hat ein kurzer Mesocon und kleine Ectoconen. Die Seitenzähne haben wohl entwickelte Ectoconen. An den Randzähnen sind Mesoconen und Ectoconen meistens zweispitzig. Es gibt 24.1.24 Zähne in einer Reihe. Kiefer und Zähne sind beinahe genau wie bei *Odontostomus* (*O. punctatissimus* Less.); aber in *Odontostomus* sind die Mesoconen etwas breiter. Ich selbst habe die Radula nicht untersucht. Der Genitalapparat ist durchaus einfach, ohne accessorische Anhangsorgane, bemerkenswert nur durch die Länge des Ganges des Receptaculum seminis. Der Kiefer ist ziemlich zart, goniognath, mit schräg liegenden Platten geziert, wie bei *Bulimulus* (Taf. XLII, fig. 25). Dieses Ergebnis war etwas unerwartet, da die Annahme nahelag, dass *Tomigerus* in die nächste Verwandtschaft von *Anostoma* gehört. Bei letzterer Gattung ist nach P. Fischer der Kiefer glatt.[1] Pilsbry vereinigt in seinen Bulimuliden Gattungen mit goniognathen und mit glatten Kiefern. Ich habe nichts dagegen einzuwenden, muss aber nur bemerken, dass die Idee der allernächsten Verwandtschaft der Gattungen *Anostoma* und *Tomigerus* durch die anatomische Untersuchung nicht bestätigt worden ist.

OXYCHONA (Mörch) Pilsbry.

Diese, früher zu den Heliciden gestellte Gattung südamerikanischer Landschnecken hat durch Pilsbry und die hier folgende Darlegung ihre richtige Stellung im Systeme bei den Bulimuliden zugewiesen erhalten. Mörch's Namen kann als *nomen nudum* keine Geltung beanspruchen, bleibt aber auf Grund der Präcisierung des Gattungsbegriffs durch Pilsbry.

Ich komme weiterhin auf die in Betracht kommenden Arten zu sprechen und gebe zunächst die Beschreibung der anatomischen Verhältnisse der mir vorliegenden neuen Art, welche ich *O. spiritualis* nenne. Über das Tier ist nichts weiter zu bemerken, als dass der Fussrücken hinten schwach gekielt war. Der Kiefer (Taf. XLI, fig. 10) wird durch eine dünne, feine, hufeisenförmig gebogene Membrane gebildet, welche im Mittelstück, wo sie einen schwach vorspringenden Zahn besitzt, schmäler ist als an den Seitenteilen, von denen jeder 16–18 schwach vorspringende nur wenig schrägliegende Rippen trägt. Die beiden untersuchten Exemplare verhielten sich in sofern verschieden, als an dem einen das Mittelstück mit Rippen besetzt, an dem anderen frei von solchen war. Die Radula trägt die Zähne (Taf. XLI, fig. 11) in regelmässigen, geraden Reihen, die jederseits vom Mittelzahn je 34 bis 36 Zähne enthalten. Der Entocon erst relativ spät,

[1] Nach einer Mitteilung Pilsbry's besteht der Kiefer von *Anostoma depressum* Lamarck aus 14 dicke Platten wie bei *Thaumastus magnificus* (*Manual of Conch.*, XIV, pl. 57, fig. 60). Er ist fester als bei *Bulimulus*, und nähert sich an den gerippten Typus.

am 9. oder 10. Zahn auftritt, der kleinere Ectocon schon früher, nämlich am 6. Zahn. Am Mittelzahn reicht die Zahnspitze nicht bis zum Hinterrande der Platte, an den Seitenzähnen ist sie vergrössert und ragt über sie hinaus. Am Genital-apparat (Taf. XLI, fig. 12) fehlen Büscheldrüsen und Liebespfeile. Die ziemlich lange Vagina setzt sich einerseits in den gewundenen Uterus fort, andererseits in das kurz gestielte, ziemlich weite Receptaculum seminis. Von letzterem geht nahe seinem freien Ende ein feiner Kanal aus, welcher sich der Uteruswand anlegt und in sie sich öffnet. Ich habe bei beiden Exemplaren durch unzweideutige mikroskopische Präparate dieses Verhältnis festgestellt. Im Receptaculum lag eine Spermatophore (Taf. XLI, fig. 13), ein sog. capreolus, von 10–12 mm. Länge und 0.6–8 mm. Dicke, welcher am einen Ende stumpf, am anderen fein zugespitzt endet, glatte, gelb braune Wandungen besitzt und durch die dünne Wand des Receptaculums durchschimmerte. Über die kleine Eiweissdrüse ist nichts weiter zu bemerken. Das Vas deferens setzt sich nicht an den Penis an, sondern an einen, demselben nach hinten aufsitzenden, verdickten Anhang, den Epiphallus, welcher am hinteren Ende den Ansatz des Retractormuskels trägt. Da, wo der Epiphallus in den Penis übergeht, ist letzterer erweitert und trägt im Innern eine stumpfe, etwas verlängerte Papille. Bevor ich auf die allgemeinen Resultate dieser Studie zurückkomme, muss einiges über die Arten bemerkt werden, welche mir zur Untersuchung vorlagen. Nur *Oxychona pileiformis* besitze ich aus Bahia und Espirito Santo, wogegen *O. lonchostoma* und *bifasciata* Burr. lediglich aus Bahia und die im folgenden zu beschreibenden neuen Arten nur aus Espirito Santo bekannt sind. Die Exemplare bilden ein neue Varietät die ich *var. dulcis* nenne (Taf. XLII, fig. 14); sie ist etwas grösser und breiter als die typische Form, von blass brauner Farbe und in gestalt der Mündung etwas abweichend.

Oxychona spiritualis n. sp. Taf. XLI, fig. 10–13.

In der kegelförmigen Gestalt kommt diese Art *O. pileiformis* nahe, ist aber kleiner und im Gewinde kürzer. Dasselbe besteht aus 7 flachen Umgängen, von denen die beiden ersten schwach gewölbt sind. Der Apex ist dunkelbraun und mit dichtstehenden Spiralfurchen und feinen Längsrippen verziert. Das Gehäuse ist eng-genabelt oder perforiert, dünn, ziemlich durchscheinend, blass- braun mit schrägen Streifen und spiralen, feinen, kaum erhobenen Leisten besetzt, welche vielfach unterbrochen und von blassgelblicher Farbe sind. Zwischen ihnen gewahrt man hie und da noch feinere, eingedrückte Spirallinien. Die Umgänge sind flach, durch eine lineare Sutur getrennt. Der letzte Umgang hat in der Mitte einen scharfen Kiel, dessen Färbung nicht von jener der umge- benden Teile abweicht. Nach vorne steigt der letzte Umgang nicht herab; seine Basis ist leicht convex. Die Mündung ist subquadratisch und schief steh end. Die Aussenlippe ist leicht

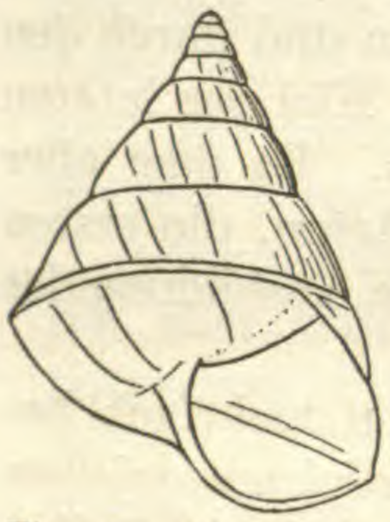

Fig. 1. *O. spiritualis* × 2.

umgeschlagen, ganz besonders in der basalen Hälfte, blass-bräunlich, fleischfarben. Die Columella ist gerade, ihr Umschlag überdeckt zum grossten Teil den engen Nabel. Die Länge der Schale beträgt 17–18 mm. der Diameter 12–13 mm. die Höhe der Mündung 9 mm.

Es liegen mir 10 Exemplare dieser Art vor, von denen 2 mit dem zugehörigen Tiere in Alcohol versehen waren. Dieselben stammen von Cachoeira am Rio Doce im Staate Espirito Santo. Von der nahestehenden Art *O. pileiformis* unterscheidet sich diese durch kürzeres Gewinde, dunkelgefärbten, feiner gestreiften Apex, stark ausgesprochene Spiralstreifung der Umgänge und Mangel der helleren Färbung am Kiel. Die Längsrippen des Apex sind gröber als bei *O. polytricha*. Bei *O. bifasciata* ist der Apex glänzend und fast glatt.

Oxychona polytricha sp. n. **Taf. XLII, fig. 16 (Schale), fig. 17, 18 (Anatomie).**

Gehäuse verlängert konisch mit schwach-gewölbten Umgängen, von denen nur der letzte eine schwache Kante an der Stelle des Kieles der verwandten Arten trägt. Das Gehäuse ist perforiert, der Apex in Farbe nicht wesentlich von dem Reste der Schale verschieden, mit überaus feinen, dichtstehenden, verticalen Rippen und äusserst schwachen Spiralfurchen besetzt. Es sind 7 Umgänge vorhanden, durch eine vertiefte Naht gut getrennt. Zahlreiche, spirale, kaum erhobene Leisten sind in regelmässigen Abständen mit feinen, kurzen Haaren besetzt, welche ein mattes Aussehen der blass-gelblichen, dünnen Schale bedingen. Zwischen den Leisten stehen noch feinere, eingedrückte, spirale Linien. Die Mündung steht schief und ist von subquadratischer Gestalt. Aussen- und Basal-lippe sind umgeschlagen, von blassrötlichgrauer Farbe. Die Columella ist gerade, ihr Umschlag ist sehr breit. In der Mitte der Aussenlippe bemerkt man bei den ausgebildeten Exemplaren eine flache, zahnförmige, gegen die Mündung vorspringende Verbreiterung, welcher an der Aussenseite eine Grube entspricht. Bei dem grössten Exemplar mit 7¼ Umgängen ist die Färbung des Mundsaumes dunkel braun-rot. Die Länge der zuletzt erwähnten Schale beträgt 24 mm., der Diameter 14.5 mm., die Höhe der Mündung 12 mm.

Auch diese Art, von der 6 Exemplare vorliegen, stammt von Cachoeira am Rio Doce, im Staate Espirito Santo. Dieselbe ist in ihrer Form und durch den Besatz mit kurzen Haaren sowie durch den nur angedeuteten Kiel des letzten Umganges von den übrigen brasilianischen Arten verschieden. Es mag aber daran erinnert sein, dass auch bei den mit Kiel versehenen Arten, die ersten Umgänge gewölbt sind, sodass man wohl annehmen darf, dass die Ausbildung des Kiels eine sekundäre Anpassung darstellt.

Die systematische Stellung der Gattung *Oxychona* ist schon mehrfach besprochen worden. So hat H. Dohrn im *Jahrbuch der deutschen malakozoologischen Gesellschaft*, X, 1883, p. 352, auf die Ähnlichkeit von *O. bifasciata* mit *Bulimulus perlucidus* hingewiesen, besonders mit Rücksicht auf die Berippung des Embryonalgewindes. Weiterhin hat dann Pilsbry, welcher zunächst *Oxychona* bei den belogonen Heliciden beliess, die Verwandtschaft mit Bulimuliden und

besonders *Drymæus* betont. Man vergleiche darüber seine Darlegungen in seinem *Manual of Conch., Pulmonata*, IX, 1894, p. 189; XI, 1898, p. 181; XIV, 1902, p. xxxvii, sowie den kleinen Aufsatz "Oxychona unmasked" in *Nautilus* XI, 1897, p. 87.

Wenn ich recht daran getan habe, *O. polytricha* in die Gattung *Oxychona* einzuschliessen, so erfährt diese Auffassung eine weitere Stütze. Es ist jedoch nötig, in dieser Frage mit aller Reserve vorzugehen; da es an Widersprüchen und weitgehenden Differenzen nicht fehlt. Die von mir untersuchte Radula von *O. spiritualis* ist recht verschieden von jener, die Pilsbry als von *O. bifasciata* abbildete (*loc. cit.* IX, Pl. 51, fig. 10). Ferner steht *O. bifasciata* auch durch den glatten Apex weit ab von den übrigen Arten und es wäre keineswegs zu verwundern, wenn in anatomischer Hinsicht, auch abgesehen von der Radula, erhebliche Unterschiede sich ergeben würden. Pilsbry bildet zwar vom Apex von *O. bifasciata* reihenweise angeordnete Grübchen ab; aber ich habe an meinen Exemplaren das nicht bestätigen können; übrigens hat Pilsbry dafür eine hundertfache Vergrösserung angewandt.[1]

Um die Angelegenheit noch mehr zu komplizieren, ergibt sich nun noch einer unerwartete Zustand in der Existenz eines Ductus receptaculo-uterinus bei *O. spiritualis*. Reste eines solchen Ganges müssen verschiedenen Abbildungen zufolge auch bei *Papuina* vorkommen und sind auch als Divertikel des Blasenganges bei *Solaropsis* bekannt. Dauernd erhalten erscheint dieser Ductus bei *Cepolis* und *Polymita* zu sein, nach Pilsbry's Abbildung, wogegen ich ihn von Bulimuliden bis jetzt nicht kenne. Indem ich die Aufklärung in bezug auf die hier diskutierten Fragen von der Ausdehnung unserer Kenntnisse der Anatomie der in betracht kommenden Gattungen erwarte, kann ich hier zunächst nur feststellen, dass die Gattung *Oxychona* für den weiteren Ausbau des natürlichen Systemes sich als besonders wichtig herausstellt und dass allem Anschein nach in ihr ein Bindeglied zwischen den *Epiphallogona* und den Bulimuliden vorliegt. Dagegen ist aber die conchologische Ähnlichkeit zwischen *Oxychona* und gewissen ostasiatischen *Papuina* eine trügerische. Soviel ich mich erinnere, war die Niere bei der untersuchten *Oxychona* nicht viel länger als das pericardium, während nach Pilsbry bei *Papuina* die Niere 2 bis 3 mal so lang ist. Auch der Apex, der bei *Papuina* glatt ist, bietet Unterschiede dar, aber andererseits ist auch der Apex von *O. bifasciata* fast glatt und ganz verschieden von jenem der übrigen Arten dieses Geschlechtes.

Ich bin früher geneigt gewesen, *Oxychona* in die Nähe von *Papuina* zu stellen, bin aber durch erneute vergleichende Studien zumal an Bulimuliden dazu gekommen, Pilsbry recht zu geben, wenn er der relativen Länge der Niere grosse Bedeutung beimisst. Von *O. polytricha* habe ich ein Tier untersuchen können, dessen Niere fig. 17 abgebildet ist. Sie misst 8 mm., der Herzbeutel 5 mm. Der Kiefer gleicht jenem der obigen Art, die Radula aber trägt die Zähne in 69–1–69 Reihen. Die Schneiden der Zähne (fig. 18 *a–c*) sind einspitzig, nur an den

[1] In 1902 hat Pilsbry die Arten mit vertical gerippten Apex in der Untergattung *Protoglyptus* gestellt.

äusseren Randzähnen (fig. 18 *c*) tritt ein kleiner Ectocon auf und ist an diesen auch die Spitze des Mittelzahnes erheblich länger, um die Hälfte der Plattenlänge über deren Hinterrand hinausreichend. Wir kommen daher zu dem Ergebnisse, dass die drei bisher untersuchten *Oxychona*-Arten erhebliche Unterschiede in den Radulazähnen aufweisen, die wohl im Laufe der Zeit zur besseren Begründung der Gattungen und Subgenera beitragen werden und dass Pilsbry im Rechte ist, wenn er *Oxychona* den Bulimuliden zuweist. Andererseits ist die vordere Verlängerung der Niere bei *Oxychona* schon eingeleitet und so mögen wohl die Pleurodontiden mit ihrer stark verlängerten Niere aus *Bulimulus*-artigen Pulmonata hervorgegangen sein.

Fam. POLYGYRIDÆ und STREPTAXIDÆ.

Diese Familie, welche Pilsbry's "Protogona" entspricht, ist von allen, die zur Gruppe der Helix-Schnecken gehören, die schlechtest bekannte und wahrscheinlich ein Gemisch von vielerlei nicht zusammengehörenden Arten oder Gattungen. Als sicherer Kern kann nur die Gruppe der nordamerikanischen Heliceen gelten, welche sich um die Gattung *Polygyra* gruppieren. Die anderen Glieder dieser Familie, *Dorcasia* in S. Afrika,[1] *Polygyratia* in Südamerika und *Coxia* in Neu-Guinea sind anatomisch fast unbekannt. Leider ist es auch mir bisher nicht möglich gewesen, diese Lücke auszufüllen. Nach *Polygyratia*-Tieren habe ich seither vergebens gefahndet. Immerhin mag es angebracht sein, einige Bemerkungen folgen zu lassen, welche gelegentlich sich von Nutzen erweisen können.

Pilsbry nimmt in seinem *Manual*, vol. 9, p. 83, drei subgenera von *Polygyratia* an: *Polygyratia* s. str. für die Arten mit Zahnleisten im letzten Umgange, *Systrophia* für diejenigen ohne solche Leisten und *Entodina* Ancey für die Arten, bei denen der Parietalcallus von der Mündungswand abgelöst ist. In einem Zusatz, p. 343, zieht dann aber Pilsbry diese Untergattung zurück, weil die typische Art, *P. reyrei*, sich durch Untersuchung des Gebisses als zu *Streptaxis* gehörig erwiesen habe. Von den zu *Entodina* gestellten Arten muss zunächst eine, *P. janeirensis* Pfr., als fraglich bei Seite gelassen werden; die Höhe der Schale von 5½ mm. bei 8 mm. Diameter schliesst sie von *Polygyratia* aus, nicht aber von *Streptaxis*, wohin sie wohl gehört. Noch für eine andere Art, *Polygyratia cheilostropha* Orb., ist die Zugehörigkeit zu *Streptaxis* wahrscheinlich, weil d'Orbigny das Tier als *gelb* beschreibt. Die Ähnlichkeit, welche zwischen *Polygyratia quinquelirata* und *P. entodonta* und verwandten Formen besteht, macht es wahrscheinlich, dass die Gattung *Polygyratia* nicht bloss teilweise, sondern ganz zu den *Streptaxiden* zu verweisen ist. Ich benutze die Gelegenheit, um hier die Beschreibung einer neuen Art einzufügen.

Streptaxis (Polygyratia) derbyi sp. n. (Taf. XLII, fig. 19).

Testa late umbilicata, depressa, discoidea, confertim costulata; spira plana, anfractus 7 carinati, ultimus antice dilatatus, vix descendens, superne prope

[1] Pilsbry hat *Dorcasia* provisorisch in der Familie *Acavidæ* gestellt, *Proc. Malac. Soc.*, London, VI, 1905, p. 288.

aperturam depressus, late-sulcatus; apertura triangularis, obliqua; peristoma incrassatum, reflexum, edentulum; labrum superne sinuatum deflexum; callus parietalis in laminam magnam excavatam linguaeformem elevatus.

Hab.: Rio Paraguassu, Bahia, O. Derby leg.

Diese kleine Art, die im Inneren des letzten Umganges keine Zahnleisten enthält, ist von anderen ähnlichen durch zwei Merkmale gut unterschieden: die dichtstehenden, schwach gebogenen, fadenförmig erhobenen Rippen der Umgänge und den Kiel in der Mitte des letzten Umganges, der zwar nicht sehr scharf, aber doch deutlich ausgebildet ist. Das verbreiterte Ende des letzten Umganges, welcher sich wenig herabsenkt, ist oberhalb des Kieles abgeflacht, mit einer tiefen Furche der Länge nach versehen und am Rande nach abwärts gekrümmt. An der Mündungswand vereinigen sich die Peristom-Hälften in einen, von der Unterlage abgehobenen, dreieckigen Fortsatz, dessen freies, spitzes Ende sich als Zahnleiste in den Umgang fortsetzt. Ich widme diese Art dem verdienten brasilianischen Geologen, meinem verehrten Freunde Dr. Orville A. Derby, welcher sie im Staat Bahia an einer Kalkfels-Wand am Rio Paraguassu fand. Die zwei Schalen sind gebleicht, ohne Epidermis, sonst gut erhalten.

In Folge der oben geschilderten Verhältnisse ist gelegentlich auch eine und dieselbe Art bald als *Polygyratia* resp. *Helix*, bald als *Streptaxis* beschrieben worden. *Strept. janeirensis* Pfr., 1851 beschrieben als *Helix janeirensis*, ist von Pfeiffer nicht abgebildet worden, wohl aber von Tryon unter dem Namen *Streptaxis* (*Discartemon*) *crossei* Pfr. im *Manual of Conchology: Pulmonata*, vol. 1, 1885, p. 67, Pl. 16, fig. 3–4. Hierbei ist ihm mit dem Namen ein Versehen passiert; denn *Helix crossei* Pfeiffer, 1862, ist eine 30 mm. grosse, gekielte Schnecke aus Siam. Es ist daher *Str. crossei* Tryon (nec Pfeiffer) synonym zu *Str. janeirensis* Pfr. Das von Pfeiffer beschriebene Exemplar stammte aus Rio de Janeiro, ebenso das von Tryon abgebildete und beschriebene. Zum Schluss sei als Resultat dieser Discussion die Beschränkung der Polygyriden auf die nordamerikanischen Vertreter und die Einreihung von *Polygyratia* unter die Streptaxiden formuliert, mit dem Vorbehalt der erforderlichen Bestätigung durch anatomische Untersuchungen.

Fam. MUTELIDÆ.

Pleiodon priscus sp. n. (Taf. XLII, fig. 20–23).

Pleiodon testa oblongo-ovata, solida, lævi, subcompressa; latere antico rotundato, subelongato, margine dorsali declivi; latere postico elongato, oblique angulato; margine dorsali subrecto, declivi; margine ventrali parum arcuato subrecto; margine cardinali antice brevi irregulariter tuberculato-crenato, postice crassiore, tuberculis verticalibus interdum subdivisis crenato.

Long. 74.5 mm.; alt. 44.8 mm., diam. 16 mm.

Hab.: Itaembi, S. Paulo.

Von dieser neuen Art liegt mir eine rechte Schale vor, deren Vorderrand teilweise zerbrochen ist und an welcher das Hinterende ganz fehlt; dieselbe ist glatt, solid, von ovaler Form mit relativ langem Vorderteile. Der Wirbel, der

klein und wenig abgesetzt ist, liegt 33 mm. vom Vorderende der Schale entfernt, also in 44/100 der Länge. Vom Wirbel aus zieht sich eine stumpfe Leiste schief nach hinten und unten über die hinter Extremität der Schale. Der vor dem Wirbel gelegene Teil der Schlossleiste hat auf einem ovalen, von einer feinen Leiste umzogenem Felde 4 länglich ovale, von oben nach unten verlaufende Tuberkel. Der hintere Teil der Kardinalleiste ist stark, bis zu 5 mm. dick und an ihm stehen die Tuberkel dichter und sind mehr in Form von vertikalen Zähnen oder Leisten entwickelt. Doch sind sie, in dem dem Wirbel zunächst gelegenem Teile etwas unregelmässig und zum Teil in der Mitte unterbrochen. Gegen das Hinterende hin stehen diese vertikalen Zahnleisten regelmässiger, aber sie sind ganz in Gesteinsmasse eingeschlossen, welche zu entfernen ohne Beschädigung der Kalkteile schwer sein dürfte. Von den Muskel-Eindrücken ist der vordere undeutlich und zum Teil verloren gegangen, der hintere oval, stark vertieft und vor ihm liegt unter der Schlossleiste die Retractor-Narbe. Die Schale dürfte in completem Zustand 80 mm. Länge und 46 mm. Höhe mit einem Durchmesser von 32 mm. gehabt haben. Sie wurde bei Itaembi im Innern von S. Paulo zusammen mit Knochen und Schuppen von Ganoidfischen von Herrn Joviano Pacheco, Paläontologen der Commissão Geographica do Est. de S. Paulo gefunden.

B. Geschichte der Heliceen von Süd-Amerika.

Die geographische Verbreitung zahlreicher Familien und Gattungen von Land- und Süsswasser-Mollusken ist eine mehr oder minder kosmopolitische, eine so breite, dass sie den Gedanken nahelegt, es handle sich bei ihnen um Formen von hohem geologischen Alter. Von vielen dieser Familien kennen wir bereits Vertreter aus mesozoischen Schichten. Es soll hier nicht unsere Aufgabe sein, die mutmassliche Geologie und Biologie der Secundär-Epoche zu discutieren und ich sehe daher auch im Folgenden von der Erörterung dieser Elemente der mesozoischen Fauna ab. Im Beginne des Tertiärs liegen die Verhältnisse schon wesentlich anders und zoologische Provinzen von ausgeprägtem Character sind unschwer zu erkennen.

In Süd-Amerika sind die ältesten, bisher bekannt gewordenen Landschnecken zwei Arten von *Strophocheilus*, die in Patagonien in den, durch ihre interessanten Säugetiere oft genannten Notostylops-Schichten gefunden, und von mir 1904 beschrieben wurden.[1] Eine derselben gehört zur Untergattung *Strophocheilus* s. str., während die andere, *Str. hauthali*, ein typischer Vertreter der Untergattung *Borus* ist, eine Art von 98 mm. Länge, welche sich unter anderem durch den starken Callus auf der Mündungs-wand characterisiert, welchen wir heute noch bei *Str. maximus*, *popelairianus*, und anderen Arten des andinen Gebietes antreffen. Das Alter der Notostylops-Schicht wird von den verschiedenen Autoren ungleich beurteilt. Für Fl. Ameghino waren diese Ablagerungen ohne allen Zweifel obercretaceisch, während Schlosser sie für ober-eocän erklärt. Ich

[1] H. v. Ihering. *Rev. Mus. La Plata*, Tom. XI, 1904, p. 238–239, Lam. II, fig. 12–14 und, *Annales del Museo Nacional de Buenos Aires*, Ser. 3, Tomo VII, 1907, p. 463.

zweifle nicht, dass beide sich irren und die betreffenden Schichten dem unteren Eocän angehören. Die Mollusken, die mich besonders beschäftigt haben, sind, so wie sie bis jetzt bekannt wurden, nicht entscheidend. Was die Säugetiere anbetrifft, so scheint mir die Entwicklungs-Höhe der Gattung *Notostylops* ebensowohl mit unter-eocänen Alter vereinbar, wie das für die Tillodonten von Nord-Amerika gilt. Zu Gunsten der Auffassung von Ameghino und mehr oder minder auch aller anderer Geologen, die sich mit diesen Ablagerungen beschäftigt haben, spricht der Umstand, dass in denselben Schichten auch Reste von cretaceischen Fischen und Dinosauriern vorkommen. An und für sich scheint mir wenig dagegen zu bemerken zu sein, wenn man für Süd-Amerika die Existenz der Dinosaurier bis in die erste Hälfte des Eocänes verlängert; aber das berechtigt noch nicht zur Annahme eines ober-eocänen Alters.

Ich halte es für sehr wahrscheinlich, dass die von mir oben erwähnten Bahuru-Schichten von S. Paulo, in welchen neben Knochen von Krokodilen und Schildkröten auch Zähne von Dinosauriern gefunden wurden, sowie der oben beschriebene Vertreter der Muteliden sich als Eocän herausstellen wird. Für unsere

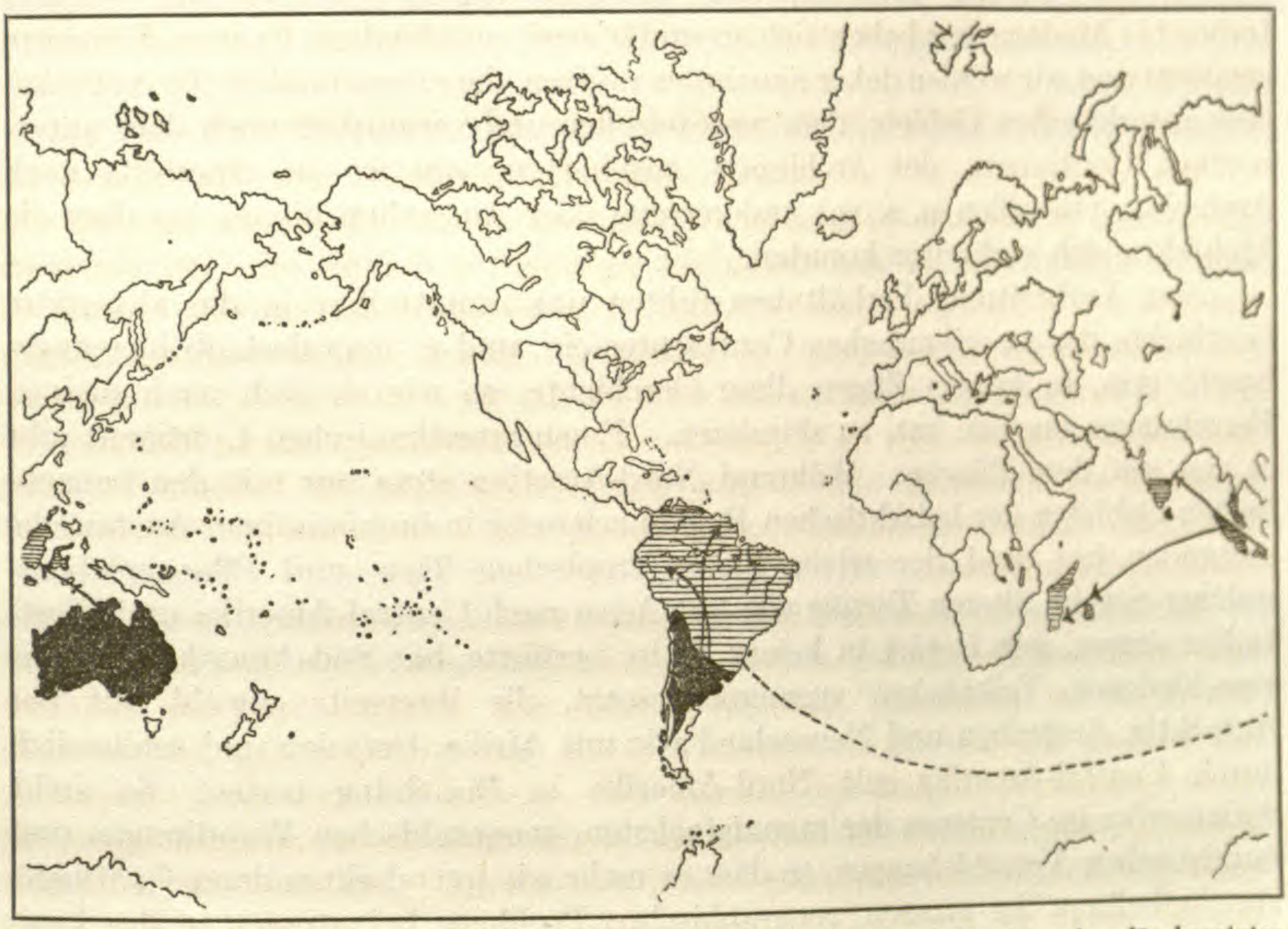

Fig. 2. Verbreitungsgebiet der Acaviden. Schwarz, primäres Gebiet; schattirt, sekundär besetztes Gebiet.

Erörterung ist es gleichgültig, ob diese Ablagerungen dem ältesten Tertiäre oder der oberen Kreide angehören. Als wichtige Tatsache registrieren wir nicht nur das Vorkommen von Arten der Gattung *Strophocheilus*, sondern die Tatsache,

dass zu jener Epoche die Gliederung der Gattung in Untergattungen bereits erfolgt war und dass es dickschalige Arten von 10 cm. Grösse gab, welche einen unmittelbaren Vergleich mit den heute noch in den Tropen-Gebieten der Anden lebenden Arten zulassen. Das setzt eine, in das Mesozoicum fallende, lange Vorgeschichte der Gattung voraus, von der wir Vertreter in den Kreideschichten der Antarktis und von Australien mit Sicherheit erwarten dürfen.

Die Gattung *Strophocheilus* schliesst sich, wie Pilsbry zuerst hervorgehoben hat, in Schale und Anatomie an die Acaviden an, von denen ich noch ein zweites Element für die südamerikanische Fauna oben nachweisen kennte, *Macrocyclis laxata*. Die Acaviden, wie wir sie jetzt kennen, sind eine der südlichen Hemisphäre eigentümliche Familie von Landschnecken, welche auch in Australien, Tasmanien, auf den Molukken, Ceylon, den Seychellen und in Madagaskar lebende Vertreter aufzuweisen haben, nicht aber in Afrika. Es gibt noch verschiedene andere Familien, welche eine ähnliche Verbreitung besitzen, so namentlich die im Süsswasser lebenden Decapoden-Krebse der Familie *Parastacidæ* und merkwürdigerweise auch der sie bewohnende Ecto-Parasit, die Trematoden-Gattung *Temnocephala*. In dem weiten Gebiete von Vorder-Indien bis Madagaskar haben sich secundär zwei verschiedene Faunen-Elemente gemischt und wir werden daher annehmen müssen, dass ursprünglich die Acaviden dem antarktischen Gebiete, dem mesozoischen und vermutlich noch dem untereocänen Continente, der Archinotis, zugehörten, von wo sie einerseits nach Archiplata (Brasilien u. s. w.) andererseits über Australien hinaus bis über die Molukken sich verbreiten konnten.

Diese Verbreitungs-Verhältnisse führen uns unmittelbar in die alttertiäre Geschichte des amerikanischen Continentes ein, und es mag deshalb hier angebracht sein, in kurzen Zügen diese Geschichte, so wie sie sich nach meinen Forschungen ergeben hat, zu skizzieren. Einen amerikanischen Continent gibt es erst seit dem Pliocän. Während Nord-Amerika stets nur mit den benachbarten Gebieten der holarktischen Region zeitweise in faunistischem Austausche gestanden hat, und der reiche Strom tropischen Tier- und Pflanzenlebens, welcher sich im älteren Tertiär von Ost-Asien nach Central-Amerika und West-Indien ergoss, sein Gebiet in keiner Weise berührte, hat Süd-Amerika sich aus verschiedenen Teilstücken zusammengesetzt, die ihrerseits sowohl mit der Antarktis, Australien und Neuseeland wie mit Afrika, Ostasien und schliesslich durch Central-Amerika mit Nord-Amerika in Beziehung traten. So steht Südamerika im Centrum der mannigfachsten, geographischen Wandlungen und faunistischen Verschiebungen, so dass es mehr wie irgend ein anderer Continent zur Aufhellung der grossen, zoographischen Probleme beizutragen in der Lage sein dürfte. Auf die südliche Zone, Archiplata, welche Argentinien, Chile und Südbrasilien einschliesst, bin ich schon kurz oben zu sprechen gekommen, indem ich auf sie den Ursprung der amerikanischen Acaviden zurückführen konnte. Die Archhelenis, deren wesentlichster amerikanischer Teil, durch Brasilien representiert wird, hat zwei eigenartige Familien von Landschnecken, die

Achatiniden und die Streptaxiden hervorgebracht, auf die ich weiterhin zurückkomme.

Diese beiden Familien werden ursprünglich auf das Gebiet der Archhelenis, das tropische Südamerika und Afrika sowie Lemurien bis Ceylon und Vorderindien beschränkt gewesen sein, haben sich aber sekundär nach den Antillen und über Hinter-Indien und die Molukken bis Australien und zum Teil Oceanien verbreitet.

Über die Archigalenis, die eocäne Landbrücke zwischen Ostasien und Centralamerika, sind von Heliceen besonders die Heliciden und die Pleurodontiden eingewandert, welche sich weiterhin zum grossen Teil über das tropische Süd-Amerika verbreitet haben, während andererseits auch Elemente der Archhelenis-Fauna, wie z. B. die Achatiniden, nach den Antillen vordrangen.

Von Nordamerika aus sind keinerlei Landschnecken über Central-Amerika nach Süd-Amerika gelangt und ebensowenig nach den Antillen, welche zur Zeit, wo diese Wanderung möglich gewesen wäre, schon vom central-amerikanischen Festland abgetrennt waren. Offenbar hat sich die nord-amerikanische Pulmonaten-Fauna im Laufe der Tertiär-Epoche so sehr an die besonderen topographischen und klimatischen Verhältnisse ihres Wohngebietes angepasst, dass von einer Einwanderung zu Ende des Tertiäres nicht mehr die Rede sein konnte. Betrachten wir nach dieser allgemeinen Übersicht die Verhältnisse der wesentlichsten, für uns in betracht kommenden Familien.

Von den Acaviden hat die chilenische Gattung *Macrocyclis* in Schale und Anatomie viel Ähnlichkeit mit den orientalischen und madagassischen Formen bewahrt, während die australischen Vertreter eine besondere Entwicklungsrichtung eingeschlagen haben. Ebenfalls in besonderem Sinne modifiziert erweisen sich die *Strophocheilus*-Arten, unter denen freilich in Schale und Anatomie ziemlich grosse Variationen zu bemerken sind. Wie schon oben bemerkt, ist die Gattung ursprünglich im Archiplata-Gebiete heimisch, wo sie schon zu Ende der mesozoischen Epoche existierte. Weiterhin erfolgte dann jene Verbreitung der Untergattungen, wie wir sie heute bemerken und infolge deren *Dryptus* auf den äussersten Nordwesten Südamerikas beschränkt wurde und die Untergattung *Strophocheilus* sich lediglich in den Gebirgswaldungen des südöstlichen Brasiliens erhielt. Die Verbreitung von *Thaumastus* wurde in zwei zusammenhangslose Gebiete, ein nordwestliches, zum grossen Teil andines, und ein süd-ost-brasilianisches zerlegt. Nur die Untergattung *Borus* behauptet das ganze Gebiet vom 40°. südlicher Breite bis zum Isthmus von Panama. Auch in dieser Gattung bestehen diescontinuierliche Verbreitungsverhältnisse eigentümlicher Art; so kennen wir *Srophocheilus martensi* Pilsbry von Matto Grosse, Rio de Janeiro und der Insel S. Sebastião vor der Küste von S. Paule. Offenbar dehnen sich früher zwischen süd-ost- und central-Brasilien grössere Waldungen aus, welche eine Verbreitung von West nach Ost über Gebiete hin gestatteten, die heute den waldliebenden Tieren ebenso unzugänglich sind wie breite Meeresarme.

In den Steptaxiden lernen wir eine Gattung der Tropengebiete kennen, welche offenbar ursprünglich dem Archhelenis Continente eigenartig war. Dieselbe hat sich sekundär über Central-Amerika bis nach Mexiko verbreitet, nicht aber nach den grossen Antillen, vermutlich, weil zur Zeit dieser Wanderung West-Indien bereits vom Festlande abgetrennt war, wogegen wir ihnen auf den, Venezuela zunächst gelegenen Kleinen-Antillen begegnen. Vertreter dieser Familie treffen wir, ausser in dem aethiopischen Gebiete, in Madagaskar, auf den Seychellen, Mauritius, Ceylon und Vorder-Indien, weiterhin auch in Hinter-Indien, auf den Molukken und in Neu-Guinea, nicht aber in Australien. Ausser *Streptaxis* und den verwandten Gattungen dürfte hieher, wie ich oben wahrscheinlich machte, auch die süd-amerikanische Gattung *Polygyratia* zu stellen sein.

Die zweite Familie des Archhelenis-Gebietes ist die der Achatiniden. Von den Unterfamilien sind die *Achatininæ* auf Madagascar und Afrika, die *Cœliaxinæ* auf West-Indien und Afrika beschränkt, während die dritte Unterfamilie, die *Stenogyrinæ* aus fünf verschiedenartigen Gruppen besteht. Von ihnen ist die *Rumina*-Gruppe wesentlich circum-mediterran, aber auch in Madagascar vertreten und vermutlich erst nach dem Oligocän nach Europa gelangt, weshalb die Bestimmungen, welche Vertreter der Gruppe schon für das Cenoman von Frankreich nachweisen möchten, offenbar auf Irrtum beruhen. Die *Leptinaria*-Gruppe ist wesentlich tropisch-amerikanisch und west-indisch. Die mit *Opeas* verwandten Formen sind über das tropische Amerika, Afrika und Indochina weit verbreitet und haben noch Vertreter in Australien und Polynesien. Die letzteren sind aber grossenteils oder alle eingeschleppt, wie das bei solchen kleinen, vielfach an Zuckerrohr, Bananen u. s. w. lebenden Schnecken leicht verständlich ist. Die grösseren, allgemeiner bekannten Formen gehören zu der *Obeliscus* und zu der *Subulina* Gruppe. Beide haben reiche Vertretung in Süd-Amerika und den Antillen, in Afrika, St. Helena, Vorder-Indien und Indochina. Die Gattung *Subulina* hat Vertreter sowohl im tropischen Amerika als in Afrika. Bemerken möchte ich bei dieser Gelegenheit noch, dass die mir zugeschriebene Behauptung, ich habe *Obeliscus obeliscus* Moric. in Taquara do Mundo Novo im Staate Rio Grande do Sul gefunden, auf einen Irrtum meines verstorbenen Freundes Clessin zurückgehen dürfte, welcher zugleich mit einer Sendung riograndenser Conchylien auch solche aus Bahia von mir erhielt, wobei dann die Fundortsverwechslung sich eingeschlichen haben mag.

Die Archhelenis-Theorie erklärt uns diese Verbreitungsverhältnisse in natürlicher Weise, wogegen kein anderer Erklärungsversuch mit den zoogeographischen und paläontologischen Tatsachen in Einklang gebracht werden kann. Ohne diese Theorie würde man gezwungen sein, an einen nordischen Ursprung der Achatiniden zu glauben, und anzunehmen, dass von Nord-Amerika aus die Vortreter der Familie nach West-Indien und Süd-Amerika gelangt seien und anderseits eine ähnliche Wander-Strasse von Europa nach Asien und Afrika geführt habe. Nun werden aber Vertreter der Familie in secundären und tertiären

Schichten von Nordamerika durchaus vermisst und nicht anders steht es in Europa, wenn man von einigen zweifelhaften Bestimmungen absieht. Die heutigen geographischen Verhältnisse sind so absolut unzureichend zur Erklärung dieser Verbreitungs erscheinungen, dass auch Pilsbry, welcher früher von einer tropisch-atlantischen Landbrücke nichts wissen wollte, sie jetzt für notwendig zur Erklärung der Verbreitung der Achatiniden erklärt. Genau ebenso steht es mit der oben angeführten Familie der Streptaxiden; auch bei ihr sind die lebenden Vertreter nicht die Reste einer ehemaligen kosmopolitisch-verbreiteten Familie; sie sind vielmehr zu keiner Zeit in der nördlichen Hemisphäre heimisch gewesen. Eine weitere Familie von Landschnecken, welche sich hier anschliesst, ist die der *Veronicellidæ*, deren Vertreter wir aus dem tropischen Amerika und Afrika, aus Madagascar, Indien, Australien und zum Teil Oceanien kennen. Für die Beurteilung dieser schalenlosen Schnecken ist in Ermangelung paläontologischen Materials die übereinstimmende Verbreitung der oben besprochenen beiden Familien massgebend.

Wie schon oben bemerkt, hat die nordamerikanische Pulmonaten-Fauna keine Beiträge zur Constituierung der heutigen Pulmonaten Süd-Amerikas geliefert. Von hervorragender Bedeutung sind dagegen diejenigen Elemente, welche von Ost-Asien über die Archigalenis nach Central-Amerika und West-Indien und späterhin nach Süd-Amerika gelangten und zu welchen vor allem die Helicidæ und die *Pleurodontidæ* (Epiphallogona Pils.) gehören. Im Eocän erstreckte sich das palaearktische Gebiet von Eurasien über die Archigalenis bis nach West-Indien und in diesem ganzem Gebiete haben wir den Ursprung der Heliciden zu suchen. Gegenwärtig sind die Cepolinen auf Amerika beschränkt, aber wir können kaum daran zweifeln, dass ihre Vorläufer auch in Ost-Asien gelebt haben. Andererseits sind manche Gruppen der Heliciden, wie *Helicostyla* immer nur auf Ost-Asien beschränkt gewesen, während wieder andere dem europäischen Faunen-Gebiete eigen waren. Begreiflicherweise hat es in einer zoogeographischen Region von so enormer Ausdehnung von jener natürliche Abteilungen gegeben. Die Palaeontologen sind früher mit der Heranziehung tropischer Gattungen für die Erklärung der Vorkommnisse des europäischen Tertiäres sehr liberal verfahren und es war eine verdienstliche Tat von Pilsbry, damit aufgeräumt und zu strenger Kritik aufgefordert zu haben. Es gibt kaum eine Tropen-Gattung, welche man nicht im europäischen Tertiär gefunden zu haben glaubte. So hat man *Columna* in recht fragwürdigen Belegstücken im europäischen und nordamerikanischen Tertiär wiederzuerkennen geglaubt, und eine grössere Menge von *Bulimus* resp. *Strophocheilus*-Arten aus dem europäischen Tertiär beschrieben. Es ist aber klar, dass im älteren Tertiär, als das Thetis-Meer noch Europa von Afrika trennte, afrikanische Pulmonaten nicht nach Europa gelangt sein konnten. Alle die merkwürdigen tropischen Züge, durch welche die europäische Eocän-Fauna so sehr überrascht, sind lediglich asiatischen Ursprungs und hierin besteht ein wesentlicher Unterschied zwischen Europa und Nord-Amerika. Im letzteren Gebiete sind die Grundzüge der heutigen Land- und

Süsswasser-Fauna schon im älteren Tertiär und in mesozoischen Ablagerungen deutlich vorgezeichnet, wogegen in Europa die Fülle der Tropenformen der Eocän-Zeit im lebhaftem Contrast zum Gesamtcharacter der heutigen Fauna steht. Über manche der in Betracht kommenden Schalen gehen die Meinungen auseinander, wie z. B. über die Vertreter von *Chloritis*. Andererseits kann man bei *Dentellocaracolus* und ähnlichen Schnecken-Schalen wohl kaum die verwandtschaftlichen Beziehungen mit *Obba* und *Pleurodonte* ernstlich in Frage ziehen. Ebenso steht es mit den vielen auffallenden Land-Deckelschnecken und die grossen *Oleacina*-Arten des europäischen Tertiärs sind aufs innigste mit den lebenden des tropischen Amerika verwandt. Diese ost- und west-indischen Verwandtschaftszüge in der europäischen Eocän-Fauna sind natürlich nicht im Mindesten auf die Landschnecken beschränkt; sie treten fast ebenso deutlich bei den Ameisen zu Tage, wo z. B. unter den Vertretern der jetzt auf das tropische Ost-Asien beschränkten Gattungen *Polyrhachis*, *Sima*, *Oecophylla* u. a. im baltischen Bernstein angetroffen werden. Ebenso steht es mit vielen anderen Insekten-gruppen. Wenn man im Auge behält, wie unendlich oft die Conchyliologen sich in der Beurteilung der Verwandtschafts-Verhältnisse der Heliceen geirrt haben und wie erst mit Hilfe der anatomischen Untersuchung eine natürliche Classification allmählich gelingt, so wird man nicht verkennen können, dass für die Beurteilung der fossilen Schalen die Berücksichtigung der allgemeinen faunistischen Verhältnisse besondere Beachtung verdient.

Die Ergebnisse, zu denen ich durch diese Untersuchungen gelangt bin, decken sich in vielen Punkten mit der Auffassung Pilsbry's, stehen aber in anderen zu ihr in Widerspruch. Bei einer einigermassen ähnlichen Methode der Untersuchung sind wir naturgemäss in vielen Punkten zum gleichen Ergebnis gelangt, so schon früher in Bezug auf die Heliciden und jetzt wiederum bezüglich der Achatiniden und Streptaxiden. Dabei möchte ich allerdings noch darauf hinweisen, dass ich es nicht für wahrscheinlich halte, dass die Familie der Achatiniden in dem von Pilsbry angenommen Sinn bestehen bleiben kann. Meine Zweifel betreffen namentlich *Opeas* und *Leptinaria*, deren systematische Stellung sich erst nach eingehender, anatomischer Untersuchung sowohl dieser Gattungen als auch von *Tornatellina*, *Cœcilianella* und anderer Gattungen von mehr oder minder unsicherer Stellung wird beurteilen lassen.

In widersprechender Weise wird von Pilsbry und mir die Geschichte der Acaviden und Bulimuliden aufgefasst. Während schon Hedley ganz richtig die Acaviden als ein antarktisches Element in Anspruch genommen hat, lässt Pilsbry sie von Südafrika aus sich verbreiten (*Non-Marine Mollusca of Patagonia*, 1911, p. 631).

Die hier vorliegenden Untersuchungen haben für die Beurteilung dieser Frage drei wesentliche Gesichtspunkte in die Diskussion gestellt:

(1) Dass *Macrocyclis* von Chile eine typische Acavide ist,

(2) Dass *Strophocheilus* innerhalb der Gattung ziemlich erhebliche Variationen, auch in anatomischer Hinsicht aufweist, bei deren Berücksichtigung die

Einreihung der Gattung unter die Acaviden noch natürlicher sich ergibt als das schon von Pilsbry vermutet wurde,

(3) Dass die Gattung *Strophocheilus* schon in der oberen Kreide von Patagonien in typischer Ausbildung angetroffen wird und dass sonach die Entwicklung der Acaviden auch schon mesozoisch sich vollzogen hat. Das Landgebiet, auf welchem die Ausbildung der Acaviden vor sich ging, kann nur das antarktische gewesen sein mit Ausbreitung einerseits nach Patagonien, andererseits nach Australien und den Molukken. Nachdem im Laufe der Tertiär-Zeit dieser Landcomplex sich mit Indien in Verbindung gesetzt hat, erreichten einzelne Glieder der Familie Ceylon sowie auch die Seychellen und Madagascar, nicht aber Afrika. Der Umstand, dass die gleichen Verbreitungs-Verhältnisse auch bei anderen Familien der Archinotis zu beobachten sind, zwingt uns zur Annahme, dass dieser westwärts gerichteten Wanderung in Madagascar ein Ziel gesetzt war, offenbar durch die während des Miocäns erfolgte Ablösung der Insel vom westafrikanischen Festlande. Beistimmen muss ich Pilsbry in seiner Meinung, dass nie ein Zusammenhang zwischen den Südspitzen von Afrika und Süd-Amerika bestand; allerdings kann ich nicht daran zweifeln, dass Afrika im älteren Tertiär noch erheblich weiter nach Süden reichte, wie dies ja auch schon Wallace hervorgehoben hat.

Die Bulimuliden, welche Pilsbry als ein Element der Archiplata-Fauna gelten lässt, sind meiner Überzeugung nach von Ost-Asien her über die Archigalenis nach Central-Amerika gelangt. Nur auf diese Weise wird es verständlich, wie sie nicht nur in West-Indien, sondern auch auf den Galapagos eine reiche Verbreitung finden konnten. Die Fauna der letztgenannten Inseln, wie wir sie zuletzt durch Dall genauer kennen gelernt haben, enthält keine unzweifelhaften Elemente der Archhelenis- oder der Archiplata-Fauna, wohl aber Elemente der orientalischen Regione wie *Helicina* und *Trochomorpha*. Alttertiäre, fossile Vertreter, welche eine definitive Antwort geben könnten, fehlen in dieser Familie ganz und so muss der zoogeographische Gesichtspunkt allein entscheiden. Dies ist um so wichtiger, als es unter den Familien, welche dem südamerikanischen und australischen Verbreitungsgebiet gemeinsam zukommen, solche giebt, deren Wanderungen sich über die Archinotis, also antarktisch vollzog und andere, welche von Ostasien her einerseits nach Südamerika, andererseits nach Australien gelangten. Die gegenwärtigen Verbreitungs-Verhältnisse sind dann mehr oder minder die Gleichen, aber die Wander-Strassen, auf welchen die Wohnsitze erreicht wurden, sind ganz verschiedenartige gewesen. Ich bemerke bei dieser Gelegenheit, dass man auch eine Familie der Anuren, die Familie *Cystignathidæ*, zu Gunsten einer ehemaligen antarktischen Verbindung zwischen Süd-Amerika und Australien geltend gemacht hat, aber, wie ich nicht zweifle, ganz mit Unrecht. Während die Mehrzahl der wichtigeren Gattungen der Landschnecken bereits in der Secundär-Epoche typisch ausgebildet war, fällt die Entwicklung der modernen Typen der Anuren ganz in die Tertiär-Zeit und nichts, namentlich auch in der Geschichte der Säugetiere, kann uns glauben machen, dass die

Archinotis sich noch lange während des älteren Tertiäres erhalten hat. Die Entstehung der Familie der Cystignathiden fällt somit in eine Zeit, in welcher die antarktische Landbrücke schon vielfach durchbrochen und incomplet war.

Der hier näher besprochenen ost-asiatisch-amerikanischen Landbrücke, meiner Archigalenis, stellt Pilsbry eine andere, mesozoische Landverbindung Nord-Amerikas mit der alten Welt entgegen (*Non-Marine Mollusca of Patagonia*, 1911, p. 632), welche von Skandinavien aus nach West-Indien geführt haben würde und auf welcher die europäische Tropenformen ihre Wanderung nach West-Indien vollzogen haben würden. Für eine solche Annahme können meines Erachtens paläontologische Tatsachen nicht geltend gemacht werden; denn im älteren Tertiär von Nord-Amerika fehlen diese Characterformen des europäischen Eocäns vollkommen. Allerdings kennen wir dieselben auch aus Asien noch nicht; aber das liegt ausschliesslich an der ungenügenden paläontologischen Durchforschung jenes Continents. Ohne Zweifel ist Nord-Amerika zu verschiedenen Malen während des Tertiäres mit den angrenzenden Teilen der paläarktischen Region in Verbindung getreten, aber diese Brücke muss weit nach Norden gelegen haben und hat wohl den schnellfüssigen Säugetieren, aber nur in geringem Masse den Landschnecken zur Verbreitung gedient. Es gibt aber noch einen anderen Gesichtspunkt, welcher eine Entscheidung der Frage herbeizuführen geeignet ist.

In dem weiten eurasischen Landgebiet der älteren Teriärzeit hat es, wie schon oben hervorgehoben wurde, zoogeographische Provinzen gegeben, und es ist daher zu untersuchen, ob ausser denjenigen alt-tertiären Elementen der Landschnecken von West-Indien, welche auch im europäischen Eocän angetroffen werden, noch andere sich vorfinden, für die ein ost-asiatischer Ursprung mit Sicherheit angenommen werden kann. Das ist nun tatsächlich der Fall. Die artenreiche Gattung *Helicina* wird von Pilsbry für uralt erklärt, wozu meines Erachtens kein besonderer Grund vorliegt; denn es handelt sich nicht um eine mehr oder minder kosmopolitische Gattung, sondern um eine solche des süd-östlichen Asiens, welche sich einerseits nach Oceanien, andererseits nach Südamerika ausgebreitet hat. Weder in Afrika noch in Europa und dem westlichen Asien hat es jemals Helicinen gegeben und sie können daher auch nicht über eine skandinavische Landbrücke nach Amerika gelangt sein, ebensowenig wie über eine Atlantis im Sinne Heer's.

Fassen wir zum Schlusse die Ergebnisse dieser Studie in einige Sätze zusammen, so hat es im älteren Tertiär vier oder fünf grössere Entwicklungs-Centren für die Landschnecken gegeben. Diese sind:

(1) Das Nord-amerikanische (Archameris), von allen in seiner Entwicklung das einheitlichste, welches niemals auf die Fauna von Südamerika irgend welchen Einfluss ausgeübt hat,

(2) Das Eurasische (Archeuris), welches von Europa über das nördliche Asien und über die Archigalenis bis Central-Amerika reichte und in welchem tropische Character-Formen von Heliceen, Agnathen, Land-deckelschnecken u. s. w. von

einem Ende bis zum anderen verbreitet waren, in welchem daneben aber auch schon zoogeographische Unter-Regionen in west-östlicher Richtung existierten. Mitglieder dieses alten eurasischen Faunengebietes, welche nachträglich von Central- nach Süd-Amerika einwanderten, sind unter anderen die *Helicidæ*, *Pleurodontidæ* und *Bulimulidæ*.

(3) Das brasilianisch-äthiopische (Archhelenis), von welchem noch dre Familien im tropischen Amerika sich erhalten haben, die Veronicelliden, Achatiniden und Streptaxiden. Dieser alt-tertiärer Continent dehnte sich über Lemurien bis nach Vorderindien und Ceylon aus. Im weiteren Verlauf der Tertiär-Zeit wurde zunächst der Zusammenhang zwischen Brasilien und Afrika unterbrochen, weiterhin jener zwischen Afrika und Madagascar und andererseits kam ein ausgiebiger Zusammenhang zwischen Vorderindien und Hinterindien zustande, wodurch es den Gliedern der beiden Familien möglich wurde, sich über die Molukken bis nach Neu-Guinea und Australien zu verbreiten, während andererseits Helicinen, Acaviden u. s. w. bis zu den Seychellen und Madagascar, nicht aber bis Afrika vordringen konnten.

(4) Das Antarktische (Archinotis), welches einerseits mit Archiplata in Verbindung stand, andererseits mit Australien und den Molukken. Ob ausser diesem Continent noch zeitweise ein süd-öst-asiatischer als Untergrund für die Fauna der orientalischen Region bestanden hat, müssen weitere Untersuchungen dartun. Als einziges, sicheres Element der Archinotis-Fauna können wir unter den Landschecken Süd-Amerikas nur die Acaviden anführen, deren ursprüngliches Verbreitungs-Gebiet ein patagonisch-antarktisch-australisches gewesen sein dürfte, das aber secundär über Indien bis Madagascar sich ausdehnte.

TAFEL-ERKLÄRUNGEN.

TAFEL XLI.

FIG. 1. *Solaropsis feisthameli* Hupe. Niere und Herz im Pericardium.
FIG. 2. *Solaropsis feisthameli*. Genitalapparat mit zwei reifen, im Uterus eingeschlossenen Eiern.
FIG. 3. *Solaropsis braziliana* Desh. Radulazähne: (*a*) Seitenzahn, (*b*) Randzahn.
FIG. 4. *Solaropsis braziliana* Desh. Genitalapparat.
FIG. 5. *Macrocyclis laxata* Fér. (*a*) Mittelzahn, (*b*) Seitenzahn, (*c*) Randzähne der Radula.
FIG. 6. *Macrocyclis laxata* Fér. Genitalapparat.
FIG. 7. *Strophocheilus achilles* Pfr. Capreolus oder Spermatophore aus dem receptaculum seminis.
FIG. 8. *Strophocheilus oblongus* Müll. Genitalapparat.
FIG. 9. *Strophocheilus granulosus* Rang. Vagina mit aufsitzender Appendicula; von oben her mündet der Oviduct, weiter unten der Gang des receptaculum seminis ein.
FIG. 10. *Oxychona spiritualis* Ih. Kiefer.
FIG. 11. *Oxychona spiritualis* Ih. Zähne der Radula, (*a*) Mittelzahn, (*b*) Randzahn.
FIG. 12. *Oxychona spiritualis* Ih. Genitalapparat.
FIG. 13. *Oxychona spiritualis* Ih. Spermatophore.

TAFEL XLII.

FIG. 14. *Oxychona pileiformis dulcis* Ih. Schale, Vergrösserung 2/1.
FIG. 15. *Oxychona spiritualis* Ih. Schale, Vergrösserung 2/1.
FIG. 16. *Oxychona polytricha* Ih. Schale, Vergrösserung 2/1.
FIG. 17. *Oxychona polytricha* Ih. Niere und Herz.

FIG. 18. *Oxychona polytricha* Ih. Zähne der Radula: (*a*) Mittelzahn, (*b*) Seitenzahn, (*c*) Randzahn.

FIG. 19. *Streptaxis* (*Polygyratia*) *derbyi* Ih. Von oben, von unten, und von der Seite gesehen; Vergrösserung 4/1.

FIG. 20. *Pleiodon priscus* Ih. Rechte Schale, Aussenansicht, natürliche Grösse.

FIG. 21. Dieselbe Schale, von oben gesehen, nat. Grösse.

FIG. 22. Dieselbe Schale, Innenansicht, natürliche Grösse.

FIG. 23. Dieselbe Schale, hinterer Teil der Schlossleiste, Vergrösserung 2/1.

FIG. 24. *Tomigerus clausus* Spix. Kiefer.

FIG. 25. *Tomigerus clausus* Spix. Zähne der Radula. 17. bis 19. Randzähne links.

TAFEL XLI.

FIG. 1. *Solaropsis feisthameli* Hupe. Niere und Herz im Pericardium.
FIG. 2. *Solaropsis feisthameli*. Genitalapparat mit zwei reifen, im Uterus eingeschlossenen Eiern.
FIG. 3. *Solaropsis braziliana* Desh. Radulazähne: (*a*) Seitenzahn, (*b*) Randzahn.
FIG. 4. *Solaropsis braziliana* Desh. Genitalapparat.
FIG. 5. *Macrocyclis laxata* Fér. (*a*) Mittelzahn, (*b*) Seitenzahn, (*c*) Randzähne der Radula.
FIG. 6. *Macrocyclis laxata* Fér. Genitalapparat.
FIG. 7. *Strophocheilus achilles* Pfr. Capreolus oder Spermatophore aus dem receptaculum seminis.
FIG. 8. *Strophocheilus oblongus* Müll. Genitalapparat.
FIG. 9. *Strophocheilus granulosus* Rang. Vagina mit aufsitzender Appendicula; von oben her mündet der Oviduct, weiter unten der Gang des receptaculum seminis ein.
FIG. 10. *Oxychona spiritualis* Ih. Kiefer.
FIG. 11. *Oxychona spiritualis* Ih. Zähne der Radula, (*a*) Mittelzahn, (*b*) Randzahn.
FIG. 12. *Oxychona spiritualis* Ih. Genitalapparat.
FIG. 13. *Oxychona spiritualis* Ih. Spermatophore.

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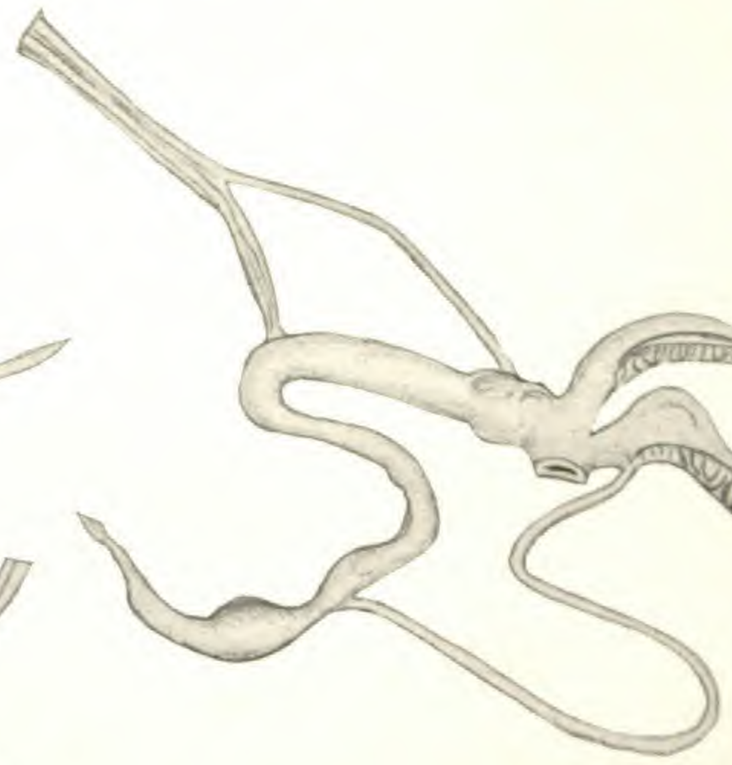

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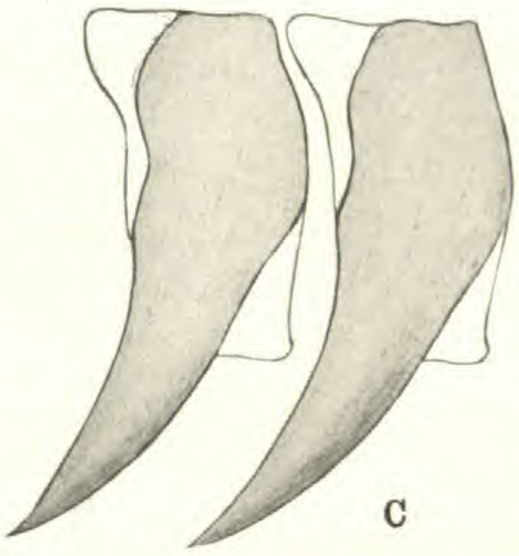

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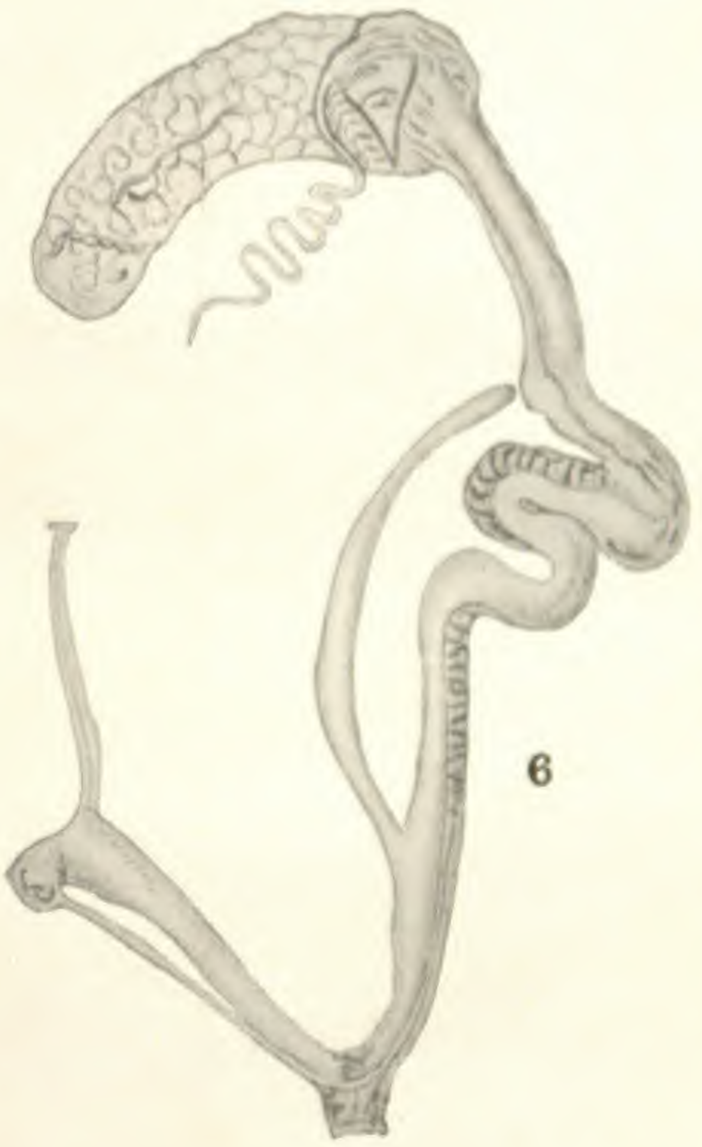

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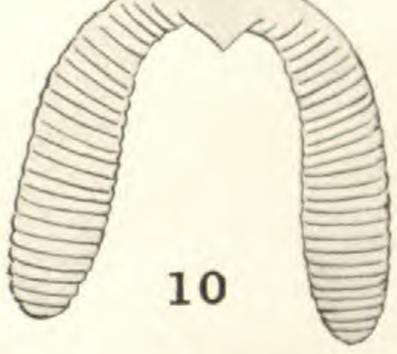

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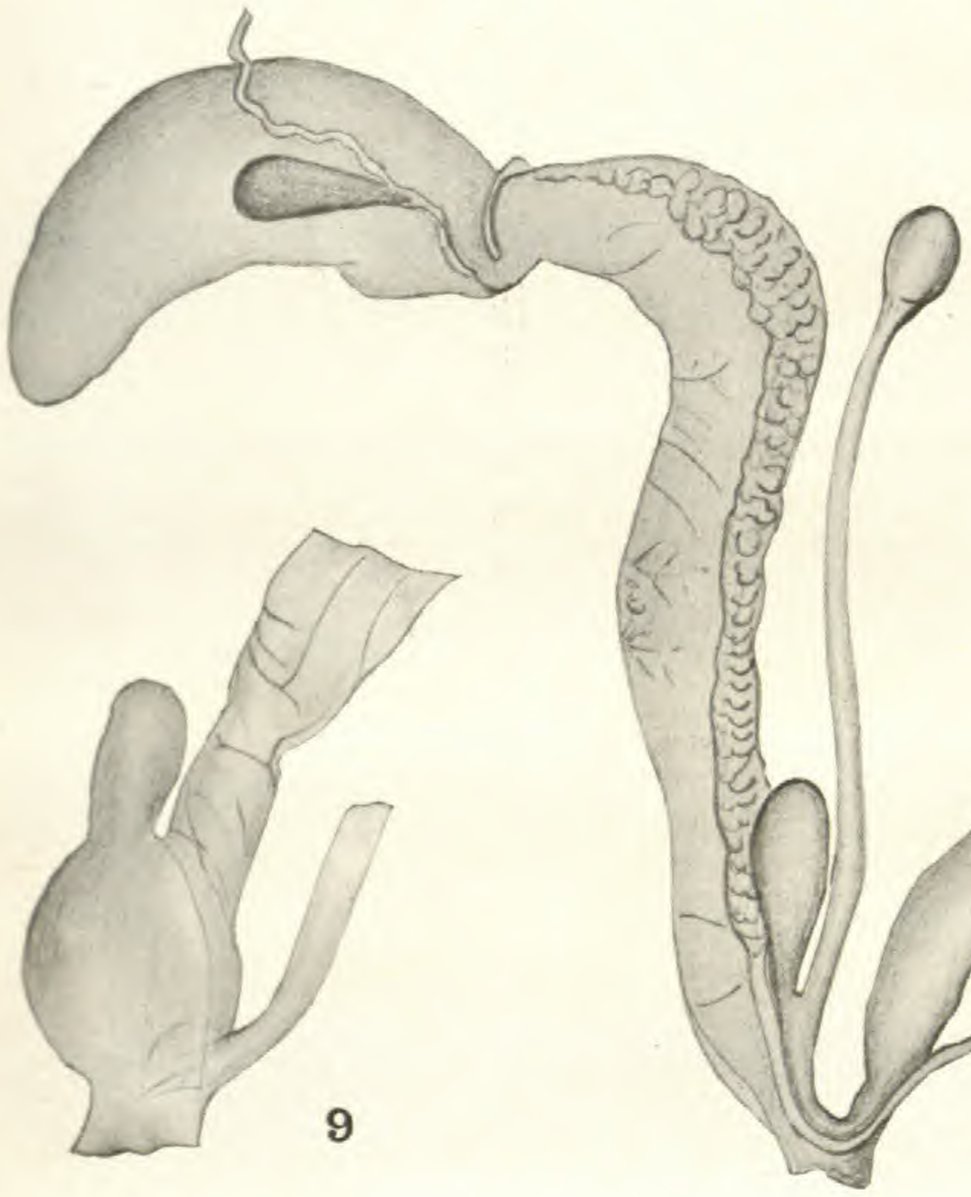

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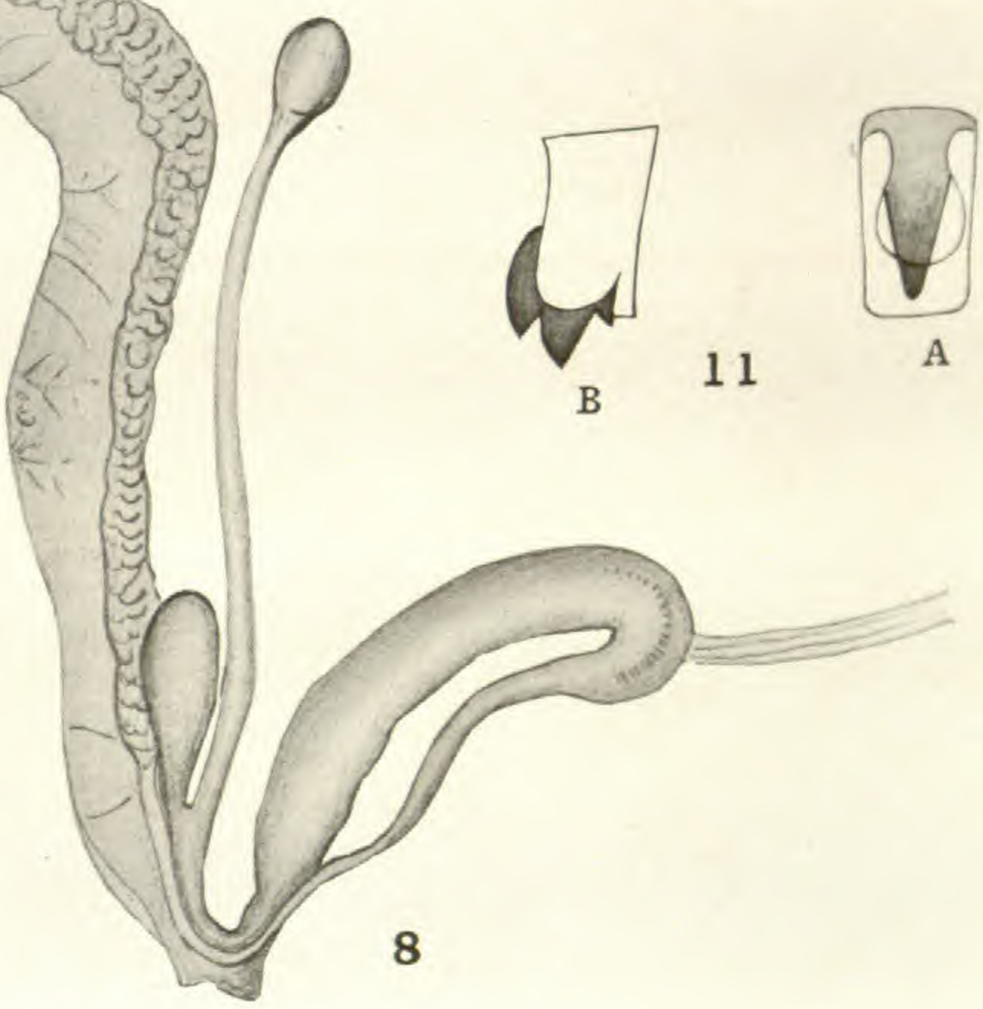

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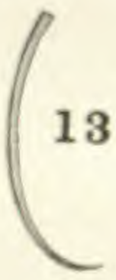

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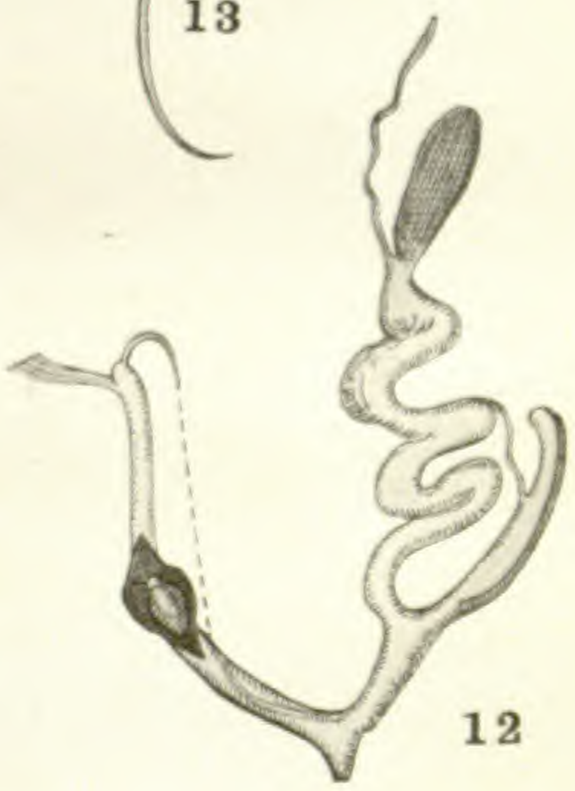

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H. VON IHERING: SÜD-AMERIKANISCHE HELICEEN

TAFEL XLII.

FIG. 14. *Oxychona pileiformis dulcis* Ih. Schale, Vergrösserung 2/1.
FIG. 15. *Oxychona spiritualis* Ih. Schale, Vergrösserung 2/1.
FIG. 16. *Oxychona polytricha* Ih. Schale, Vergrösserung 2/1.
FIG. 17. *Oxychona polytricha* Ih. Niere und Herz.
FIG. 18. *Oxychona polytricha* Ih. Zähne der Radula: (*a*) Mittelzahn, (*b*) Seitenzahn, (*c*) Randzahn.
FIG. 19. *Streptaxis* (*Polygyratia*) *derbyi* Ih. Von oben, von unten, und von der Seite gesehen; Vergrösserung 4/1.
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FIG. 24. *Tomigerus clausus* Spix. Kiefer.
FIG. 25. *Tomigerus clausus* Spix. Zähne der Radula. 17. bis 19. Randzähne links.

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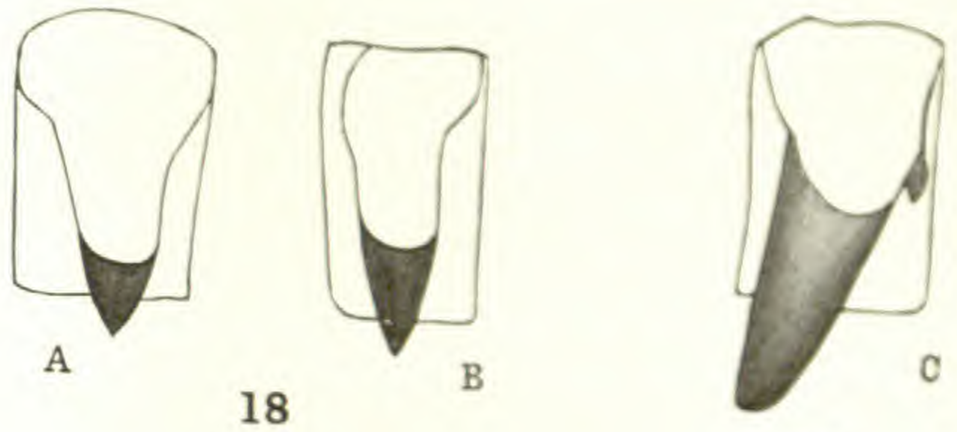

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C 18

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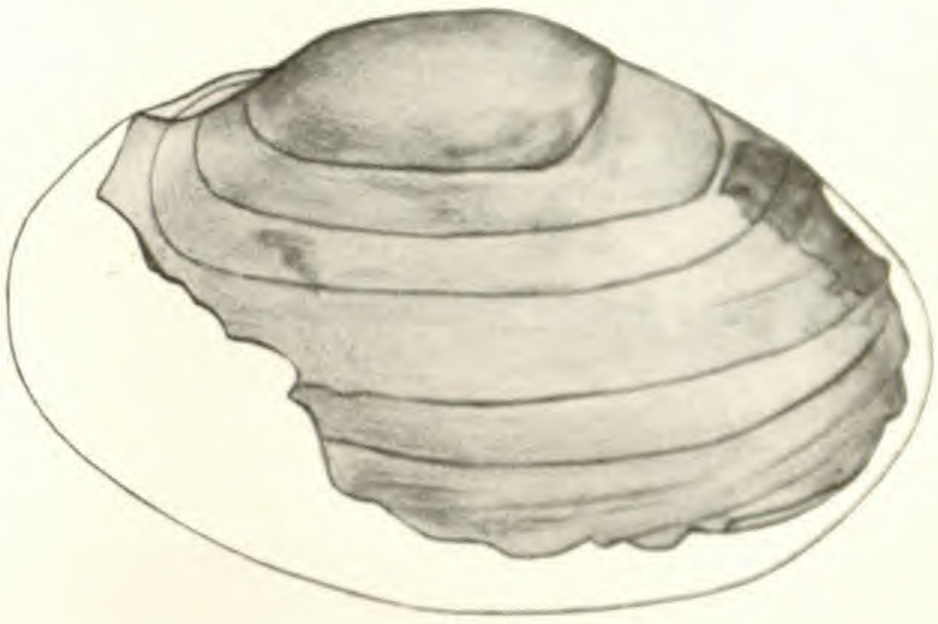

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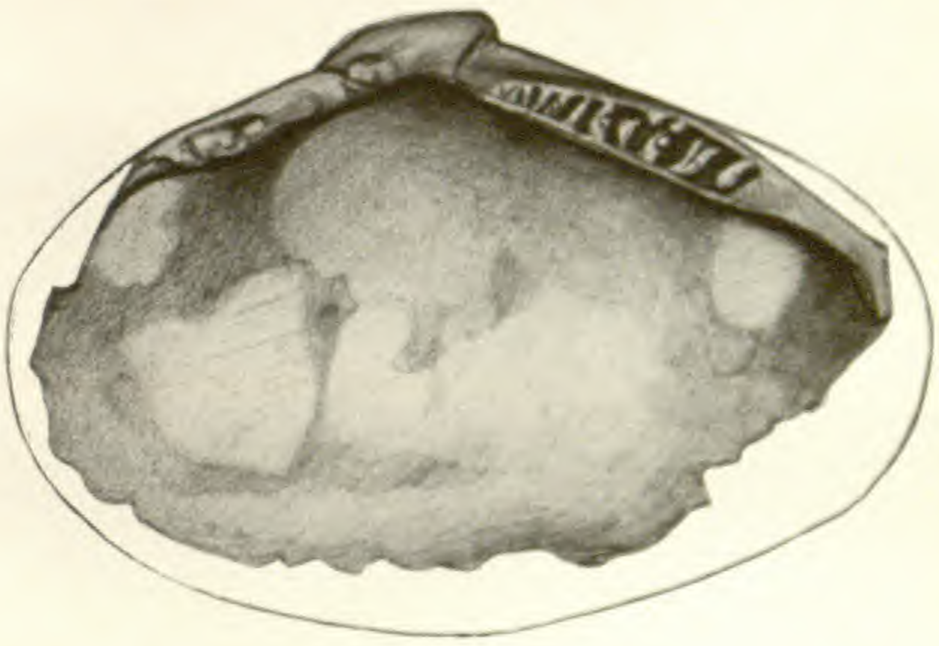

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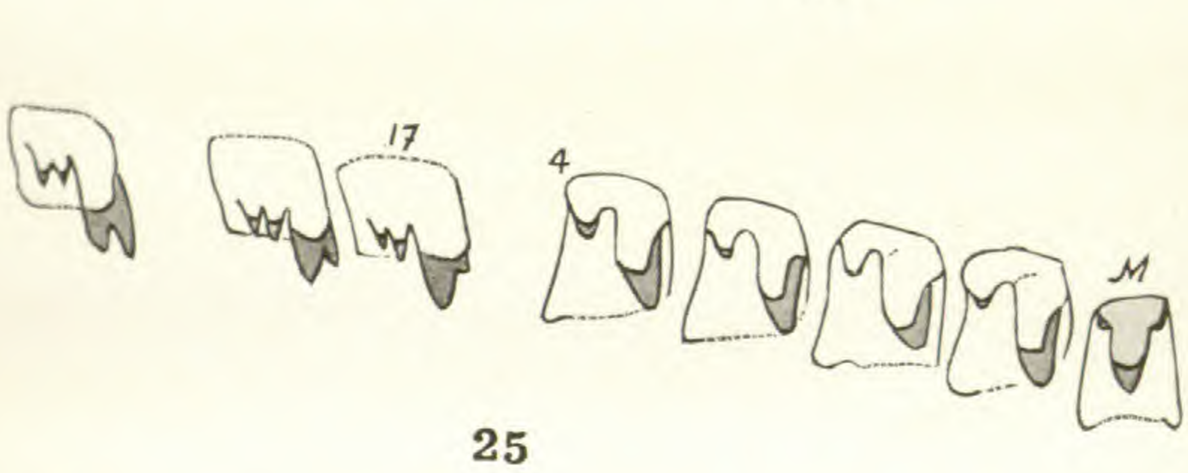

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23

Experimental Studies on Nuclear and Cell Division in the Eggs of Crepidula

BY

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PLATES XLIII–LIX

PHILADELPHIA
1912

EXPERIMENTAL STUDIES ON NUCLEAR AND CELL DIVISION IN THE EGGS OF CREPIDULA.

By Edwin G. Conklin.

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Introduction.

Many problems of development, heredity and evolution center in the study of the causes and nature of differentiation, and particularly of the early differentiations of the egg. Some of these differentiations have been traced back to very early stages of development without finding their real beginnings, and indeed it is clear that a definite sequence of morphological differentiations must be preceded at every stage by a definite organization, *i. e.*, differentiation and integration, of the developing substance, even though this antecedent organization be only one of molecules and atoms. But many, and indeed most morphological differentiations arise in the course of development by a process of epigenesis, or creative synthesis, from other differentiations more or less unlike in kind. The great problem of development is to determine, as far as may be possible,

the sequence and origin of differentiations and the extrinsic and intrinsic factors by which they may be modified. Much has already been accomplished in tracing the sequence of morphological differentiations to earlier and earlier stages of development, but relatively little has been learned as to the nature and causes of differentiation itself. By the observation of purely normal processes one sooner or later comes to a place beyond which he can make little if any progress in the study of such problems, but the history of biology in the last twenty-five years has shown that much may be learned by the comparison of normal and abnormal processes, and especially by the combination of observations of normal processes with experiments which may be varied indefinitely.

In two previous publications (1897, 1902) I described in detail the normal development of the gasteropod, *Crepidula*, particularly as regards the phenomena of cell-lineage and of nuclear and cell division. The present work comprises the results of a series of about 260 separate experiments, extended over a period of more than ten years, on the eggs of *Crepidula plana*, the species which was principally used in my previous work. The eggs of this animal afford unusually fine material for the study of the normal processes of development, but they are less favorable for experimental work and for the following reasons: (1) Fertilization takes place within the oviduct, and eggs capable of development cannot be obtained until after they are normally fertilized and laid. (2) The laid eggs are inclosed in capsules within which they undergo the whole of their embryonic development, and when removed from these capsules they do not continue to develop normally for more than three or four days. (3) The rate of development is so slow, about one month being required to reach the stage of the free-swimming larva, that it is difficult to rear larvæ from eggs which have been subjected to experiment. But while these conditions make this material unfavorable for experimental studies on fertilization or the development of larval or adult organs, they do not seriously interfere with experimental studies on cleavage and the early differentiations of the egg. On the contrary the eggs of *Crepidula* are peculiarly favorable for such studies. In no other egg with which I am acquainted is it possible to study the details of cell organization so satisfactorily as in this one. The eggs may be obtained in large numbers and may be stained and mounted entire so as to show minute details of cell polarity, the structure and division of nuclei, centrosomes and cytoplasm, and the relation of cell growth and division to differentiation. In such a case the advantage of the study of whole eggs over that of sections is very great; one can see at a glance the relative positions of all cell constituents, and of all the cells in the cleaving egg, and one may readily study and compare these minute details in hundreds of eggs, whereas this could be done in the case of sections only by the most laborious methods and then only in a relatively small number of eggs. Of course sections have also been used in cases where it seemed necessary in order to answer questions which were left more or less uncertain by the evidence derivable from whole preparations.

In general the method of procedure was to take eggs in a given stage of development, subject them for a definite time to altered conditions, and then return them to normal conditions where they were allowed to remain for varying lengths of time. As just indicated most of the eggs were fixed and stained according to the methods described in my previous papers on *Crepidula* (1897, 1902). In practically all cases the eggs experimented on were carefully compared with others of the same laying kept under normal conditions. For descriptions and figures of the stages in the normal development of *Crepidula* reference should be made to the papers just mentioned.

The present work will deal with the following topics in the order named: (1) Abnormalities found in nature. (2) The cleavage of isolated blastomeres. (3) The effects of pressure on nuclear and cell division. (4) Effects of electric currents of varying strengths. (5) Effects of abnormal temperature. (6) Effects of ether. (7) Effects of decreased oxygen tension in the medium. (8) Effects of carbon dioxide. (9) Effects of hypotonic solutions. (10) Effects of hypertonic solutions.

I. Abnormalities Found in Nature.

(Plates XLIII, XLIV. Preparations 942–945.[1])

On the whole there are remarkably few cases of abnormal eggs in nature; probably not more than one egg in a thousand shows any abnormality whatever. In plates XLIII and XLIV are shown the principal types of such abnormalities. Most of these, as for instance figs. 2–5, 9, 11–13, 15, and probably 18–26 are due to pressure. Since the eggs are laid in very thin and delicate capsules and are crowded close together, about 175 eggs being found in each capsule, it is really surprising that a larger number of eggs do not show the effects of pressure.

The most usual effect of pressure during mitosis is the formation of a lobe of cytoplasm opposite one or both ends of the amphiaster (figs. 2, 12, 13, 20). Such a lobe, as I have maintained in a previous paper (1902), is an evidence of reduced tension in the cell membrane at the points opposite the ends of the spindle. More recently, I (1912) have observed that lobes may be formed opposite the poles of the *future* spindle, while the cell is still in a resting condition; such a condition is shown in figs. 15 and 19, and indicates that the axis of the future spindle is already marked out in the resting stage preceding division, by points of reduced tension in the cell membrane. Whether this is the chief or only cause of the orientation of the spindle in the cell, cannot at present be affirmed or denied, but it seems very probable that it is at least one of the factors determining such orientation. Associated with the formation of these lobes the spindle itself is sometimes shifted toward one pole or the other so that its equator no longer lies in the typical plane of cell division. In fig. 13 the mitotic figure has been moved so that one of the daughter nuclei lies in the division

[1] See Catalogue, p. 559.

plane while the other is far away from that plane. In fig. 9 the entire spindle has been moved into one of the daughter cells, and the division plane between the cells has cut off a cell containing two daughter nuclei from one containing none. In this case a *Zwischenkörper* or mid-body is present in the plane of division, although the entire mitotic figure lies to one side of that plane. This seems to indicate that the mid-body may be formed, or at least may persist, independently of the mitotic figure.

Other abnormalities of division which are probably due to pressure, are found in figs. 22–25; here the number of macromeres is increased from four to six, seven or eight, and this is probably due, as experiments show, to pressure in the vertical axis during the third cleavage. Such increase in the number of macromeres is not to be interpreted as the result of an "anachronism of cleavage" (Roux), *i. e.*, to the substitution of a later cleavage for an earlier one, nor are the eight blastomeres so formed comparable to those of the 8-cell stage of the normal egg. *On the contrary this cleavage is one not represented in normal eggs but is a new one which has been intercalated, and though in point of time it is the third cleavage, it is morphologically like the first and second cleavages and not like the third cleavage of the normal egg; it gives rise to no micromeres and serves merely to increase the number of macromeres to a number larger than four.* In subsequent cleavages each one of these macromeres gives rise to three micromeres (ectomeres) exactly as if it were one of the four normal macromeres. From the directions of these divisions and from the size and quality of the resulting cells it is perfectly evident that the micromere formation from each of these macromeres takes place exactly as in a normal egg. Each macromere which reaches the animal pole gives off three micromeres (ectomeres). In figs. 23 and 24 where six macromeres reach the animal pole, and one lies far below, near the vegetal pole, there are six micromeres of the first set ("quartet"); in fig. 24 five of the macromeres are dividing in a læotropic direction to form the micromeres of the second set, and it is evident from the position of the nucleus and sphere that the sixth and smallest macromere will also give rise to a micromere of the second set when it divides. In fig. 25 it is evident from the positions of the spindles in the five macromeres that the third set of micromeres are being formed, and although it is not possible in this figure to identify certainly all the micromeres of the first and second sets, it is probable that there are six micromeres of the second set, and six of the first, each of the latter having budded off in læotropic direction a small "turret cell." In fig. 26 there are but three macromeres, two of which have given rise to three sets of micromeres, whereas the third macromere (*D*) is dividing for the first time.

In several cases in which more than four macromeres are present the nuclei of some of the cells are either irregular in form or multiple in number. Thus in fig. 22 there are several scattered nuclei in four of the cells (three at the animal, and one at the vegetal pole), and in fig. 24 there is a triaster in one cell and double nuclei occur in two micromeres and in one macromere. These are probably karyomeres or partial nuclei, due to polyasters, such as are seen in fig. 16, and

such an egg would probably divide at once into seven or eight cells, the number of macromeres in this case being due immediately to abnormalities in the mitotic figure rather than to pressure. In this case the initial causes of these triasters and polyasters can only be conjectured; probably cell division was suppressed by pressure, while centrosomal and nuclear division went on, as will be explained later.

A few other types of abnormal cleavage occurring in nature have been observed. The eggs shown in figs. 6, 7, 8, have not divided into several macromeres, but the yolk has remained undivided while two separate micromeres have been cut off at the animal pole of the single macromere. The mitoses by which these cells were formed were abnormal, as is shown by the character of their nuclei, but the positions of the centrospheres, and the relation of the cells themselves to the macromere, as well as the position of the spindle in fig. 6, indicate that these small cells may correspond to the first and second micromeres of the normal egg. If this be true we have here another evidence of the fact that *the number of micromeres is proportional to the number of macromeres, in every case three and only three micromeres being cut off from each macromere, i. e., with one macromere the micromeres are formed in sets of one, with two in twos, with four in fours, with six or eight in sixes or eights, etc.* In this connection it is interesting to note that Bigelow (1902) found in the egg of *Lepas* that the single macromere of that egg gave rise successively to one first, one second and one third ectomere and then to one mesomere, and he concluded that such a type of cleavage might be derived from the "quartet" type by the suppression of the first and second cleavages of that type.

Fig. 18 shows an egg in the 4-cell stage in which the nuclei are entirely lacking in two of the cells, although other parts, such as sphere and mid-body, are present. I do not know how such an abnormality has arisen but it may be that the nuclei were extruded after the division of the cells. On the other hand fig. 21 shows an egg in which the nuclei continued to divide in normal rhythm although the cell body did not, three of the spindles of the third cleavage being found in one cell, without proper orientation, while the spindle in the other cell is normal in position.

Finally figs. 27, 28, 29 represent a few eggs and embryos from a great number in which the yolk mass or endoderm was not overgrown by the micromeres, thus giving rise to exogastrulæ. The lot of eggs showing these abnormalities was found in a place where the sea water was diluted with fresh water, and the experimental study of the effects of diluted sea water on the eggs shows that this is the probable cause of these abnormalities.

These are the only types of abnormalities which I have found among the many thousands of normal eggs which I have studied; among these, however, are representatives of several forms of abnormalities of cell division which have occurred in my experiments.

II. Cleavage of Isolated Blastomeres.

(Plate XLV. Exps. 855–857, 887–892, 921–931, 957–959.)

The cleavage in *Crepidula* belongs to that type which I once (1897) called "determinate," in which every blastomere has a definite prospective significance, giving rise to a definite part of the embryo and larva. Is this "determinism of development" due to intrinsic causes, to the character of the oöplasm in a blastomere, or to environmental influences acting on the blastomere, such, *e. g.*, as the interrelation between different blastomeres, etc.? Is the "potency" of a blastomere of the *Crepidula* egg as limited as is its "prospective significance"? This is a problem to which much attention has been devoted in the case of the development of other animals, but although most of my observations on this subject in the case of *Crepidula* were made many years ago, nothing has hitherto been published regarding it. It is undesirable at this place to review the very extensive literature on this subject, which Korschelt and Heider call *Das Determinationsproblem*, and for an excellent discussion of the work on this problem prior to 1902, reference is made to Korschelt und Heider, *Lehrbuch der vergleichenden Entwicklungsgeschichte, Allgemeiner Theil, II Capital.*

In general, the blastomeres of the egg of *Crepidula* are closely adherent to one another so that it is difficult to separate them without injury; nevertheless in the anaphase of the first and second cleavages the blastomeres become so rounded that they touch one another only by relatively small surfaces and at this stage they may sometimes be separated by pressure or by shaking, without injuring the cells. Sometimes such isolation is brought about by diluted sea water, or by ether, but the injury to the cells in such cases is usually considerable so that the subsequent development of such isolated blastomeres is complicated by such injury. In an egg with such a definite cleavage pattern as that of *Crepidula*, where the position, size and histological character of many cells are highly characteristic, the study of the cleavage of isolated blastomeres is of more than ordinary interest. It is here possible to determine with certainty whether the cleavage goes forward in strictly partial fashion, whether it undergoes certain modifications although still remaining partial in other respects, or whether the blastomeres return to the condition of the unsegmented egg after their isolation.

In practically every instance it is found that the isolated blastomeres round up and in subsequent cleavages the cells come into contact with one another forming contact surfaces which are often different from those of the normal egg; this flattening of cells against one another usually involves slight rotation of the cells and a consequent slight shifting of the cell axes with reference to the original cell complex. But with this exception the cleavage of isolated blastomeres is strictly "partial." The general direction of cleavages, and the size and histological character of the blastomeres are in all cases like those of the normal egg. If isolation takes place in the 2-cell stage each ½ blastomere divides equally,

and in a slightly læotropic direction, into two macromeres (fig. 30, *A*, *B*) and each of these macromeres then gives rise to a first micromere of normal size and quality by dexiotropic cleavage (fig. 31, 34), then to a second one by læotropic cleavage (fig. 35), and then to a third one by dexiotropic cleavage (fig. 37), exactly as in normal eggs. If isolation takes place in the 4-cell stage each ¼ blastomere (macromere) gives off a first micromere by dexiotropic, a second by læotropic, and a third by dexiotropic cleavage (figs. 32, 33, 34). If one of the four macromeres is separated from the other three, the ¾ blastomeres, if uninjured, behave as they would if the egg were still entire, except that they move together to close the gap left by the missing macromere (figs. 39, 41, 43, 44), unless one or more of them are injured, in which case the gap may not be completely closed (figs. 36, 40, 42). Every ¼ macromere whether isolated or joined with one or more others, gives rise to three micromeres of typical size and quality by divisions which are typical in direction.

In all cases the relative sizes of macromeres and micromeres are approximately the same as in normal eggs, and the micromeres are always free from yolk spherules. The direction of the spindle axes, the direction and extent of rotation of the cells in telokinesis, and the final positions of nuclei and spheres in the cells are always the same as in normal eggs, with the single exception, mentioned above, that owing to the closing of the gap left by the removal of one or more macromeres the direction of cleavage, with reference to the whole, is slightly altered. This closing of the gap is caused chiefly by the turning in or rotation of entire cells and the axis of each of these cells, as marked by its nucleus and centrosome, remains unchanged.

The subdivisions of the micromeres of typical eggs are also highly characteristic; the first division of the first micromeres is læotropic and very unequal, the small peripheral products being the turret cells ($1a^2$–$1d^2$), while the large central products are the apical cells ($1a^1$–$1d^1$). The first division of the second micromeres ($2a$–$2d$) is dexiotropic and approximately equal. The first division of the third micromeres ($3a$–$3d$) is læotropic and slightly unequal, the peripheral product being smaller than the central one. In all of these respects the subdivisions of the micromeres of partial eggs are wholly typical; in the first division of the first micromere the spindle is eccentric in position and the division gives rise to a small "turret cell" ($1a^2$–$1d^2$) whether the partial egg consists of one, two or three quadrants (figs. 33, 35, 37–44); in the first division of the second set of micromeres the spindles are not eccentric and the resulting daughter cells are approximately equal (figs. 37, 41, 42, 44); in the first division of the third set of micromeres the spindles are again eccentric in the cell and the peripheral daughter cells are smaller than the central ones (fig. 43).

Later subdivisions of the micromeres of partial eggs are also entirely typical for each quadrant. The second division of the apicals ($1a^1$–$1d^1$) is unequal giving rise to a larger peripheral cell, the "basal cell" ($1a^{1,2}$–$1d^{1,2}$) and a smaller "apical cell" ($1a^{1,1}$–$1d^{1,1}$); at the same time the right half of each micromere of the

second set gives off a small central cell, the "tip cell," and a large peripheral one; while the left half of each of these micromeres reverses this, giving off a small peripheral cell from a large central one; there is thus formed an "ectodermal cross" with its center at the animal pole and with an arm running out over each macromere and ending in the "tip cell" which is larger in quadrant *D* than in any of the others (see stippled cells, fig. 43). In all of these respects the ¾ eggs shown in figs. 43 and 44 are entirely typical though they lack all the cells of one quadrant. Finally in the partial egg shown in fig. 43 the macromere 4*D* has given rise to the mesentoblast, 4*d*, which has divided into right and left halves, M^1 and M^2, in a manner entirely typical; on the other hand when the macromere *D* is lacking no mesentoblast cell is formed. Other partial eggs caused by diluted sea water are shown in figs. 135, 144, 151, 155. These also illustrate the principle that the development of isolated blastomeres is entirely typical so far as the cleavage of each quadrant is concerned. The cleavage from the 4-cell stage on is, in the language of Roux, "a mosaic work consisting of four independently developing vertical pieces." These results are in essential agreement with those reached by Roux (1892), Chabry (1887), Crampton (1896), Wilson (1904), Conklin (1905) on the cleavage of isolated blastomeres in eggs of animals having "determinate" types of cleavage. Of course where individual blastomeres are not peculiar in size and quality it is not possible to determine to what extent the cleavage of isolated blastomeres is atypical. In *Crepidula* the individual peculiarities of the blastomeres are so marked that we have here one of the best possible opportunities for the study of this problem.

III. Effects of Pressure on Cleavage.

(Plates XLVI, XLVII, XLVIII. Exps. 849–854, 884–886, 893–920, 1000–1004.)

Another method of studying the determinism of cytoplasm and nuclei in the cleavage stages is to subject the eggs to pressure so that the spindle axes and cleavage planes are turned out of their normal positions. Such experiments were performed by Pflüger, Roux, Born, and O. Hertwig, on amphibian eggs; by Driesch, Morgan, and Ziegler, on echinoderm eggs; by Ziegler, on ctenophore eggs; and by Wilson, on the eggs of *Nereis*, etc. In this way the early cleavage furrows may be displaced from their normal positions so as to form linear series or flat plates of cells, the distribution of oöplasmic substances (yolk, cytoplasm, etc.) to the blastomeres may be greatly changed and the nuclei which in normal eggs would have gone into micromeres may be caused to go into macromeres. Driesch and Hertwig in particular have maintained that these pressure experiments demonstrate the totipotence of the cytoplasm and karyoplasm, since normal development may result from eggs in which both of these plasms are abnormally distributed. Nevertheless Driesch has shown, and most of the other investigators named above confirm this conclusion, that the structure of the cell protoplasm differs in different axes, and that the cleavage of isolated blasto-

meres from the animal pole differs from that of blastomeres from the vegetal pole. On the other hand practically all investigators agree that the nuclei of the cleavage cells are not only totipotent but that they are qualitatively all alike. The following experiments on the effects of pressure on *Crepidula* eggs confirm in the main the conclusions reached by previous investigators.

1. *Modifications of the Cleavage Pattern.*

The eggs of *Crepidula plana* are laid in thin, transparent, membranous capsules; about 175 eggs are found in each capsule, and the walls of the capsules are usually flattened together in one plane so that opposite walls are in contact at the middle of the capsule while the eggs are crowded into the ring-shaped space at its periphery. Owing to the crowding together of the eggs in these flattened capsules it sometimes happens that eggs which have not been subjected to experiment show the effects of pressure, as previously mentioned, but such modifications are relatively rare in a state of nature. In most of the experiments the eggs were subjected to pressure within the capsules; in some instances (Exps. 897, 900–908, 910, 911, 916–920) they were removed from the capsules before being subjected to pressure. Whether the eggs were pressed within the capsules or after removal from them the results were essentially the same. In general eggs which had been removed from the capsules were more frequently broken and injured than when they were pressed within the capsules. The capsules, or freed eggs, were placed under cover glasses, or between glass slides in dishes of fresh sea water, or they were placed in a Ziegler compressorium through which a current of water was kept running, and were allowed to remain in such positions for from four to eighteen hours. After removal of pressure the eggs were either fixed at once or were allowed to develop under normal conditions for periods of time varying from one to sixteen hours. Varying degrees of pressure were thus applied in different axes and for various lengths of time to eggs in different stages of development. In most cases pressure was applied until the spherical eggs became flattened disks, and it was surprising to note how much flattening the eggs would bear without bursting.

In cases where pressure was applied during the maturation of the egg, and parallel with its chief axis, the polar spindle may remain near the center of the egg (fig. 68) and the polar bodies may be abnormally large, as in fig. 45 where the second polar body is as large as an ordinary micromere; or a large "yolk lobe" may be formed at the vegetal pole. In cases where large polar bodies are formed their nuclei are usually correspondingly large. Not infrequently all division is stopped during pressure and I think that in such cases the pressure is most frequently in the direction of the normal spindle axis.

The results of pressure during the cleavage of the egg are essentially the same, so far as cell division is concerned, as during the maturation, *i. e.*, the spindles may be turned out of their normal positions, the relative sizes and positions of the daughter cells may be altered, the cleavage may be suppressed,

or lobes may be formed on the surface of the cells, usually opposite the poles of the spindle. Figs. 46, 47, 49 show eggs in which the first cleavage was made unequal; figs. 47, 48, eggs in which lobes were formed near the vegetal pole; fig. 50 is an egg which was pressed in the direction of the second spindle axis and in which cleavage was halted in one of the macromeres (*CD*) while the other continued to divide; fig. 57 is an egg, pressed in the same direction as fig. 50, in which the four macromeres are arranged in linear series; fig. 51, an egg which has divided into three cells, each with several nuclei, probably the result of a triaster. In no instance, however, have I found evidence that triasters or tetrasters may be formed as the immediate result of pressure. On the other hand they are frequently due to the continuance of nuclear and centrosomal division after the suppression of cell division, the result being that two or more nuclei and centrosomes are left in a single cell body and in subsequent mitoses triasters, tetrasters or polyasters may be formed. Figs. 69–72, 74 show eggs in which the second cleavage spindles are out of their usual positions, and in which the division of the cell body is partially or entirely suppressed. These eggs were subjected to the action of the electric current, while being pressed between graphite-plate electrodes, but it is probable that the abnormalities shown are due to pressure rather than to the electric current. In fig. 73 an egg is shown in which one of the first two blastomeres contains two nuclei, while the other one contains a well formed spindle without any chromatin. This is probably the result of pressure during the first cleavage, whereby both daughter nuclei were forced into one blastomere, leaving only a centrosome in the other blastomere, as in fig. 13. Figs. 69, 72, 75 represent successive stages in the development of three different eggs in which the first cleavage furrow was suppressed, probably by pressure between the graphite-plate electrodes.

Pressure during the third and fourth cleavages in the direction of the chief axis of the egg leads to some very interesting modifications of the cleavage type. The micromeres which normally lie on top of the macromeres and which are about 1/20 the volume of the latter, may thus be caused to lie in nearly the same plane as the macromeres and to equal them in size. Of course this is brought about by the turning of the spindles from a position nearly parallel with the egg axis to one at right angles to that axis. It has been a matter of surprise to me to see how difficult it is to bring about this change in the position of the spindles and how much the eggs must be flattened in order to accomplish it. Even under the greatest flattening which the eggs will stand without bursting, the spindles still preserve a little of their original slant, the end of the spindle nearer the polar bodies being at a little higher level than the opposite end. Consequently in most of my experiments the cells which are formed at the apical (central) ends of the spindles are at a little higher level than those at the outer ends, and the former are usually smaller than the latter, though containing yolk and being much larger than typical micromeres. Fig. 52 represents an 8-cell stage in which the third cleavage in quadrants *C* and *D* was nearly normal; in *A* and *B*

the "micromeres" $1A^1$, $1B^1$ are very large and contain yolk; in the macromere $1A^2$ the nucleus and cytoplasm lie on the animal pole side of the cell, on the other hand $1B^2$ is entirely cut off from the animal pole. A study of the later cleavages of such eggs after pressure has been removed shows that only those cells which preserve a cytoplasmic area on the animal pole side give rise to micromeres; therefore, $1B^2$ being cut off from the upper half of the egg is incapable of forming micromeres and is in the condition of the cell $1D^2$ in figs. 23 and 24. Figs. 53–55 are 8-cell stages in which some of the "micromeres" are much larger than usual and contain yolk. It is interesting to observe that all such "micromeres" are dividing synchronously with the macromeres and in general in the same direction as the macromere from which they were derived. In fig. 53, the "micromeres" $1A^1$, $1B^1$, $1D^1$ are dividing in a direction similar to that of the normal micromere (see fig. 56, 1*c*) but the spindle is so placed in each cell that the peripheral portion instead of being a small "turret" cell will be a large yolk-containing cell; the position of the spindles in the macromeres $1B^2$–$1D^2$ is læotropic, which is characteristic of the fourth cleavage (formation of second quartet) but in $1A^2$ the position of the spindle is dexiotropic. In fig. 54, the normal position of the spindles is reversed in $1A^1$, and $1A^2$. In fig. 55 the spindle positions are all dexiotropic, the reverse of normal, though the position of centrosome and nucleus in $1B$ indicates that the direction of cleavage in this cell will be læotropic.

In fig. 76 is shown an egg in which pressure in the direction of the chief axis of the egg, during the third cleavage, led to the formation of eight macromeres, each of which has now given off one micromere; the direction of division at the third cleavage was prevailingly læotropic, at the fourth cleavage dexiotropic in quadrants, *C* and *D*, and prevailingly læotropic in *A* and *B*. Fig. 77 shows another egg pressed in the direction of the chief axis after the formation of the first quartet, and during the formation of the second and third quartets; the abnormalities in the latter are indicated by the lettering and arrows between cells. Fig. 78 represents an egg which was pressed between graphite-plate electrodes for two minutes, during which time a current of 5 mil. amp. was passed between the electrodes, the egg was then left in sea water under normal conditions for 22 hours; there are six macromeres and twelve micromeres; four of the macromeres and three of the micromeres are dividing, the stage corresponding to that of the formation of the second set of micromeres in normal eggs. The pole at which the micromeres form differs in different blastomeres and is widely different from that of normal eggs. Fig. 79 shows an egg which was pressed for ten minutes between graphite-plate electrodes between which a current of 5 mil. amp. was passed, the egg was then left in normal sea water for 16 hours. The second set of micromeres are being formed and the first set are dividing, but the egg shows plainly the effects of pressure in the direction of the chief axis.

The egg shown in fig. 56 was evidently pressed after the formation of the first set of micromeres (1*a*–1*d*) which are quite normal; on the other hand, the

macromeres of the second set are larger than normal, and $2a$ and $2c$ contain a quantity of yolk. In figs. 58 and 59 pressure in the direction of the chief axis of the egg has led to the formation of the first set of micromeres between the macromeres and in the same plane with them. In fig. 59 each of the eight cells has divided or is dividing in a dexiotropic direction (with the possible exception of the cells in quadrant D). The direction of this cleavage is therefore like that by which the first set of micromeres are formed, and there are thus formed almost simultaneously eight protoplasmic cells at the animal pole which may be regarded as micromeres of the first set. In fig. 58 the 16-cell stage is completed; it consists of four "micromeres" of the first set, each of which by læotropic division has given off peripherally a micromere, two of which ($1b^2$ and $1d^2$) are much larger than normal, while the other two ($1a^2$ and $1c^2$) have been given off on the vegetal side; the macromeres have also given rise to "micromeres" of the second set, which contain yolk and are much larger than usual; this division was læotropic in A, B, C, but dexiotropic in D. Fig. 60 represents an egg which was pressed 4 hrs. and freed 6 hrs. Quadrants A, B, D are normal except that the "turret" cells in quadrants B and D ($1b^2$, $1d^2$) are larger than normal; in quadrant C the turret cell ($1c^2$) is also larger than normal and the micromere of the second set ($2C^1$) is as large as a macromere. In all cases the direction of division is normal. Fig. 61 is normal except in quadrant A; evidently the first set of micromeres was formed in typical fashion but the second division of macromere A was nearly equal, giving rise to $2A^1$ and $2A^2$, the former of which has again divided into $2A^1$ and $2a^1$, but the latter ($2A^2$) gives rise to no micromere of the second set, all of its second micromere material having gone into its sister cell $2A^1$. Fig. 62 represents an egg like the preceding one in which the first division of macromere C was nearly equal; the upper one of the macromeres thus formed ($1C$) has divided, giving off an apical cell $1c^1$; the elongation of this cell and the spireme in its nucleus indicate that it will soon cut off a turret cell at its peripheral pole; the position of cytoplasm, nucleus and centrosome in $1C$ indicates that this cell is about to give off a micromere of the second set ($2c^1$), whereas the same indications show that the macromere $2C$ has given off a micromere of the second set ($2c$), but none of the first set; in other respects this egg is normal. In fig. 63 there are six macromeres, owing to the fact that the first division of A and D was nearly equal; each of these six macromeres has produced a micromere of the first set, while one (C) has produced a micromere of the second set. The positions of the nuclei and spheres in $1B$, $1A$, $1D$, $1D^1$ indicate that the next division in these cells will be læotropic, and will give rise to micromeres of the second set; on the other hand in $1A^1$ it will be dexiotropic. In fig. 64 the conditions are much like those shown in fig. 58, viz., the first micromeres have given off, or are just forming the "turret" cells; two of these, $1b^2$, $1c^2$, lie at the lower pole; the second micromeres are larger than usual and contain yolk; one of these, $2a$, was formed by a dexiotropic division, the others by læotropic division as in normal eggs. In fig. 65 quadrants C and D are approximately normal, $2B$ has been crowded under the

ectomeres, while *A* gave rise to a micromere of the first set, much larger than usual, which has divided equally into $1a^1$ and $1a^2$, the latter being much larger than in the other quadrants; the second division of *A* was a nearly equal one, the second quartet cell $2A^1$ being a macromere. In fig. 66 the axis of pressure was at right angles to the egg axis, *B* having been crowded under *A*, and *D* under *C*; the first, second and third quartets and their subdivisions are normal, except that some of the cells are slightly displaced. Fig. 67 represents an egg which was flattened in the direction of the egg axis; the three sets of micromeres and their subdivisions are approximately normal; the usual ectodermal cross is present (its cells are stippled); the fourth quartet cell (4*d*) has been formed and is larger than usual. My material showing the effects of pressure does not include stages older than the egg shown in fig. 67, owing probably to the retardation of cleavage in eggs which have been much pressed; in these same experiments many eggs which were pressed less, and are therefore normal, have reached the 64–72-cell stage. In some of the experiments the eggs were under pressure for 18 hrs. and were fixed 4 hrs. after being freed; in others they were pressed 16 hrs. and freed 16 hrs., yet in no instance has the cleavage of abnormal eggs advanced beyond the 42-cell stage.

2. *Differential and Non-Differential Cleavages.*

Owing to the slow rate at which pressed eggs of *Crepidula* develop, it is not possible in this case to determine the morphogenetic potency of the various atypical blastomeres which are thus produced. However the cleavage patterns of these pressed eggs show that a meridional cleavage, approximately parallel with the chief axis, divides the egg substance in such manner that every blastomere so formed subsequently divides as a normal macromere. If four macromeres are present, as is the case in normal eggs, each gives rise to three ectomeres; if pressure is applied during the third cleavage, so that five, six, seven or eight such macromeres are formed each still gives rise to three ectomeres; if the pressure is applied after the first set of micromeres are formed so that the macromeres divide equally in the fourth cleavage and by a vertical plane, each of these macromeres in subsequent division gives rise only to micromeres of the second and third sets. If "micromeres" are formed at the third cleavage, which are much larger than usual, as in figs. 53, 59, 62, 63, *et al.*, these cells do not become ectomeres in their entirety but they cut off protoplasmic ectomeres at the animal pole from yolk-containing entomeres at the lower pole. If the third cleavage is rendered equatorial, each of the cells of the animal pole gives rise to three sets of ectomeres, but those at the vegetal pole produce no ectomeres. If the cleavage plane is oblique, between meridional and equatorial, the cells so formed may give rise to a varying number of ectomeres, and in general only macromeres which reach the animal pole produce three ectomeres, while the farther the macromeres are removed from that pole the smaller the number of ectomeres which they produce.

These facts are important with reference to one of the greatest problems of

embryology, viz., the factors of embryonic differentiation. The earliest differentiations of the fertilized egg are those which occur during cleavage; the differentiations of cleavage lead to the formation of cells which are qualitatively and quantitatively different, and if the causes of unequal and dissimilar cleavages can be found, an important step will have been taken toward the solution of the causes of embryonic differentiation. The facts presented above suggest that the substances of the egg are stratified from the animal to the vegetal pole, and that only oöplasm of a definite sort is given off in the ectomeres (micromeres) leaving material of a different sort in the entomeres (macromeres).

On the other hand when the more fluid substances which normally lie at the animal pole are thrown by centrifugal force into one of the first two blastomeres leaving only yolk and a small amount of cytoplasm in the other blastomere, the cell with the greater quantity of fluid substance gives rise to only three ectomeres, while that with the smaller quantity also gives rise to three ectomeres (see Conklin, 1912). Evidently therefore it is not merely the quantity of fluid substance in the macromere, nor the stratification of the more dense and less dense oöplasmic substances, which determines whether or not three ectomeres shall be formed.

It seems necessary to conclude as Lillie (1906) and Morgan (1910) have done that the heavier or lighter substances of the egg, which may be stratified by centrifugal force, are not morphogenetic substances, but are mere inclusions in the real morphogenetic material. So far as yolk is concerned it is known that it is a relatively dense inclusion which may be stratified at the distal pole of the centrifuged egg, or may even be thrown out of the egg without seriously modifying the morphogenetic processes. The same is true of the lighter oily or watery substances which may be stratified or thrown out at the proximal pole of the centrifuged egg. When both these denser and lighter inclusions are eliminated there is left the clear substance of the middle zone in which the nucleus and centrosome usually lie; and even the most of the material of this middle zone may be transferred from one of the first two blastomeres to the other, without interfering with the development of either blastomere. In what part of the cell, then, does the polarity, symmetry, and morphogenetic organization reside?

In *Crepidula* a nucleus, centrosome and sphere, plasma membrane and probably a minimal quantity of the protoplasm of the middle zone (hyaloplasm) must be present in a blastomere if it is to develop at all, and it must be in some one or more of these parts, or in their relations to one another, that the organization resides. In my experiments the one visible thing which is left unchanged in these centrifuged eggs is the axial relation between nucleus, centrosphere and cortical layer. It is extremely difficult to move the mitotic figure by centifugal force,—apparently it is anchored to the cortical layer by threads of denser protoplasm,—and it is possible that a framework of such threads connects nucleus, centrosphere and cortical layer, and thus preserves the axial relation mentioned above. Such threads of denser protoplasm may possibly

correspond to the "ground substance" of Lillie (1906), but it is to be noted that I do not regard these threads as the seat of polarity and organization, as I understand Lillie to do, but merely as a framework which preserves the typical axial relations of nucleus, centrosphere and cortical layer. But it is insufficient to say that the organization of the egg determines the position of the mitotic figures and consequently the cleavage pattern. More specifically the central spindle, or netrum, usually forms at right angles to the cell axis (the axis passing through the centrosome, nucleus and mid-body) and in the plane which separates the nuclear halves or gonomeres. Owing to the movements of telokinesis in the cleavage of *Crepidula* the cell axes undergo regular changes with respect to the axis of the egg as a whole; the direction of telokinetic movements is such that the centrosomes always move toward the animal pole and toward the point where the previous cell constriction began. Consequently successive cleavage planes are not at right angles to one another, but the cleavages take place in a "spiral" manner. A further consideration of this subject is reserved for another paper.

Equality or inequality of division is due in part to the localization of different oöplasmic substances, and in part to local reductions in the tension of the cell membrane. Indeed telokinetic movements, and consequently the direction of division as well as the equality or inequality of daughter cells, are associated with local variations of tension in the cell membrane. O. Hertwig (1892) long ago maintained that the spindle lies in the direction of least resistance in the cell; certainly this is not the principal factor which determines the position of the cleavage plane, as Jennings (1896), Zur Strassen (1896) and I (1897) have shown. Doubtless the spindle lies in the axis of least resistance in many cases, but the position of the spindle does not make that axis the one of least resistance. It is probably owing to local reductions in the tension of the cell membrane that there is an axis of least resistance, and these reductions of surface tension are not caused by the position of the spindle, but *vice versa*. Indeed the characteristic movements of the cell contents in all stages of division (prokinesis, metakinesis, telokinesis) and consequently the initial direction of the subsequent spindle, as well as the equality or inequality of cleavage, are probably associated with local variations in the tension of the cell membrane. But more important than any of these factors are the mitotic movements of the cell contents, which begin with the dissolution of the nuclear membrane in the prophase and which carry the spindle into certain definite positions in the cell and there bring about constriction of the cell body in a particular plane which usually passes through the equator of the spindle.

The position of the spindle, then, is due to at least four factors viz: (1) The separation of daughter centrosomes at right angles to the cell axis and in the plane which separates the gonomeres. (2) Telokinetic movements by which the cell axis undergoes regular changes with respect to the axis of the egg as a whole. (3) Local reductions of tension of the cell membrane in certain axes, or increase of tension in other axes, by which an axis of least resistance is established

in the cell. (4) Mitotic movements of the cell contents, which cause the spindle and the surrounding plasma to move into certain axes and positions in the cell.

The quality of a cell, that is, the character of the cell substance which it contains, appears to be due in the main to the relation between the spindle axis and the stratification or localization of cell substance at the time of its formation, *i. e.*, to the way in which the cleavages cut through the different cell substances. *The morphogenetic value of a blastomere appears to depend primarily upon the kind of protoplasm, apart from mere inclusions, such as oil and yolk, contained in the cell, though it is known that the nuclear substance may influence the prospective potency of a blastomere in cases of regulation or restitution.*

In the ascidians, as I have pointed out elsewhere (1905) "the prospective significance of a blastomere is a function of its position" (Driesch) only because of its relation to the organization of the egg as a whole—because of the particular morphogenetic substances which go into it—and not because of its position relative to other blastomeres. The experiments described above, on the effects of pressure and of centrifugal force, on the cleavage of the eggs of *Crepidula*, indicate that the same principles are involved in this case also, though the cytoplasm of this egg contains a larger amount of inclusions or non-morphogenetic materials and is more capable of regulation than is the case with the ascidian egg.

So far as the nucleus is concerned these pressure experiments indicate that the divisions are non-qualitative. When the third cleavage spindle is forced into an equatorial plane and the cells divide meridionally instead of latitudinally, as in normal eggs, the subsequent development of the extra macromeres thus formed may be quite normal, each giving rise to three ectomeres, just as if the normal number of macromeres were present. Therefore the organization of the nucleus is not such that each of its divisions has a specific morphogenetic value; on the contrary the nuclear divisions are non-differential and in this respect, non-morphogenetic. Of course the nucleus has a definite structure, polarity, symmetry, etc., but its division by mitosis is such that the daughter nuclei are alike.

IV. Effects of Electric Current.

(Plates XLVIII, XLIX. Exps. 995–999, 1100–1123, 1140–1142.)

Many authors beginning with Fol (1873) have emphasized the resemblance between the mitotic figure and the lines of force in a magnetic field. Nevertheless attempts to identify the forces at work in the two cases have largely failed. Errera (1890) was unable to find any effect of electricity or magnetism upon cell division in *Tradescantia*. Nevertheless Ziegler (1895) and Gallardo (1896) maintained that the mitotic figure was the expression of a bipolar force, and the latter held that this force was probably electrical in nature. Hartog (1902, 1905, 1907) also held that the mitotic figure is an expression of a bipolar force —his mitokinetic force—which he likens to, but does not identify with, electricity. Hartog, as well as Gallardo in his earlier work, held that the poles of the spindle were heteropolar, bearing opposite signs, though Gallardo has since

abandoned this view and now (1909) thinks that both poles of the spindle are alike and are positively charged, while the chromosomes are negatively charged.

Schücking (1903) and Delage (1908) found that artificial parthenogenesis may be induced by an electric current, but they made no study of the effects of the current on cell structures. R. Lillie (1903) showed that isolated nuclei and spermatozoa, suspended in cane sugar solution, through which an electrical current is passed migrate with the negative stream, while cells with voluminous cytoplasm migrate with the positive stream. He concluded therefore that the colloidal particles composing the chromatin carry negative charges, the cytoplasmic particles positive charges.

In four subsequent papers on the physiology of cell division R. Lillie (1905, 1910, 1911[1], 1911[2]) points out many parallels between electric and mitotic phenomena. In the first of these papers (1905) he holds that "the disposition and relative positions of many colloid aggregates in the cell, especially the chromosomes and chromatic filaments during mitosis, indicate that mutual electrostatic attractions and repulsions play an important part in determining their position and movements." The formation of the spireme and of the equatorial plate, as well as the arrangement of the chromosomes with respect to one another and to the poles of the spindle in amphiasters and triasters was simulated by the use of floating magnetized needles exposed to the attractive or repellant action of magnetic poles. Such models were held to indicate that the astral centers have a repellant action on the chromosomes and therefore, since chromosomes are negatively charged aggregates, these astral areas must also be negatively charged. In the last of the papers cited Lillie (1911[2]) concludes "that by taking account of the changes of potential resulting from alterations in the permeability of electrically polarized membranes certain characteristic phenomena of mitosis are susceptible of consistent physico-chemical explanation."

Pentimalli (1909, 1912) and McClendon (1910) confirm Lillie's conclusion that the chromatin bears a negative charge, but McClendon is unable to confirm Pentimalli's observation that in the root-tip of the hyacynth the chromosomes are carried through the cell walls toward the anode. He finds however that the basophile substances of the cell, as well as the mitotic figures as a whole, migrate toward the anode. Roux (1891) found that a "morphological polarization" of the egg substances of different animals, not unlike the stratification produced by centrifugal force, was caused when an electric current was passed through the egg. All of these effects are undoubtedly due to convection currents within cells. Baltzer (1908, 1911) has criticized the views of Hartog and Gallardo, showing that triasters and tetrasters in echinid eggs demonstrate that the poles cannot have opposite signs and that spindles may form where there is no chromatin. In his later work Gallardo (1909) admits that all poles are alike in sign, but denies that a true spindle may be formed where there is no chromatin. He affirms that spindles without chromatin are only apparent, and never lead to cell division. One may admit the truth of the latter half of this statement without granting that the first half is true. Certainly cells do not usually divide if chromatin is

lacking, though this has been observed by Ziegler, Wilson and others, but the initial spindle (netrum) is formed without the presence of chromatin in the spindle, and perfect spindles of full size may occur without any trace of chromatin, as Boveri (1897) and Baltzer (1908) have shown, and as is figured in figs. 73 and 90 of this paper.

The fundamental difficulty with Gallardo's theory as a theory is its inconsistency. If the poles of the spindle are of like sign, as he now holds, and the chromatin is of opposite sign, the movements of chromosomes toward the poles in the anaphase find an explanation, but not their movements into the equatorial plate. To explain the latter, Lillie supposes that astral centers and chromatin are of the same sign, viz., that both bear negative charges, but this would not explain the movements of the chromosomes toward the asters in the anaphase, for two daughter chromosomes not only separate from each other, but they cling to other chromosomes and as plates move close to the poles; such movements cannot be explained by assuming that centrosomes and chromosomes bear like charges and hence repel one another. Leduc (1902, 1904) holds that the mitotic phenomena cannot be explained as the result of electric phenomena, whereas they may be the result of diffusion phenomena. About the same time (1902) I maintained that astral radiations are diffusion streams, and the results of later work have not caused me to change this opinion. Mitotic phenomena are complex and they are doubtless due to several factors, rather than to a single one. Damianovich (1907) believes that several forces may be at work, viz. electricity, polarity, diffusion phenomena, surface tension, hydrostatic polarity and probably different chemical energies; and Gallardo (1909), to whose review I am indebted for a knowledge of this paper, apparently approves this conclusion. Stomps (1910) holds that the separation of chromosomes is due to the formation and growth of vacuoles between the daughter chromosomes. But it is evident that the phenomena of mitosis and their causes must be more specifically analyzed before we can construct theories as to the mechanics of the process.

If the mitotic figure is the expression of electrostatic charges carried by colloidal particles composing the chromosomes, centrosomes and cytoplasm it seems probable that the figure would undergo modifications of form or orientation if an electric current were passed through it, and such modifications should throw light upon the nature of the charges carried by different portions of the figure. With this thought in mind I have subjected the eggs of *Crepidula*, during cleavage, to the action of a constant current. In my first experiments with the electric current, which are catalogued at the end of this paper as Nos. 995–999, the eggs, still within their capsules, were placed in a paraffine trough about 5 cm. long, 1 cm. wide and ½ cm. deep, containing a small quantity of sea water. In Exp. No. 1120 the trough was 12 cm. long and about 2 cm. wide and 1 cm. deep. In the paraffine wall at each end of the trough a boot-shaped porcelain electrode was imbedded, with the toe projecting into the trough. Dilute copper sulphate

was put into the legs of the boots and into this the wires from one or more dry batteries dipped. The impressed voltage varied from ¼ volt to 1 volt, but the amperage was not measured. Under the conditions described it is uncertain to what extent the current actually went through the eggs. When the trough was filled with eggs and the amount of water was very small many of the eggs were penetrated, but in general the resistance of the eggs was so much greater than that of the surrounding water that many of the eggs were left in a normal condition, and it may be assumed that few of the eggs were penetrated by the full strength of the current.

Nevertheless many eggs show by certain unmistakable signs that they were penetrated by the current. Not infrequently eggs were killed outright and even fragmented or disintegrated; in some cases they were coagulated together into a single mass. Where the injuries were less gross, but where the eggs were undoubtedly killed there is no distinct separation between protoplasm and yolk, and the chromatin of the resting nuclei, the chromosomes and spindle fibers of division stages have dissolved more or less completely (figs. 80–86). In some cases the chromosomes have disappeared from the amphiaster, leaving the spindle fibers and polar rays intact (fig. 90). Where the injury was less severe the substances of the egg may be stratified by the current, the nuclei and cytoplasm being driven to one pole while the yolk remains at the other. Strands and streamers of cytoplasm may extend through the yolk or over its surface, thus indicating the direction of movement, as in figs. 88, 91. This dislocation of oöplasmic substances is in many respects similar to that produced by centrifugal force. In this respect my results confirm those of Roux, Pentimalli, McClendon, *et al.* This stratification is the result of convection currents within the cell and it throws little if any light upon the nature of the mitotic figure. For this reason it seemed desirable to employ weaker currents and at the same time to take such precautions as were possible to insure the current penetrating the eggs. In Exp. 1120 a current of 1 mil. amp. was passed through the trough between porcelain-boot electrodes for 45 min., but this current was so weak that it produced no effect whatever upon the eggs.

Later experiments with the electric current were performed under the following conditions: The eggs, either within the capsules or after they had been liberated, were placed on a graphite plate, which had previously soaked in water, the water was drained off and a second graphite plate, similar to the first, was laid over the first, the two being separated by cover glasses of a thickness about equal to the diameter of the eggs. Each plate was connected with the poles of a dry battery, or of several dry batteries in circuit. The strength of the current used varied from 50 mil. amperes to 1 mil. ampere, but the exact area covered by the eggs on the graphite plate was not measured in every case. In general, however, the eggs covered an area about 3 cm. square. With a current of from 40–50 mil. amperes which was used in experiments 1100–1103, the eggs were coagulated almost at once and stuck fast to the anode. In all later experiments, the current

was reduced to at most 7 mil. amperes, and in several cases to 5, 2, or 1 mil. ampere. The duration of the current varied from 15 minutes to 1 minute and the eggs so treated were fixed either at once or from 1 to 60 hours after they had been returned to dishes of sea water. All of these experiments are catalogued as Nos. 1100–1143, at the end of this paper.

Many eggs placed between the graphite plates show the effects of pressure; many of those shown on Plate XLVIII are of this sort. The abnormalities in the positions of the spindles shown in figs. 68–74 are duplicated in the pressure experiments, while the dislocation of cells shown in figs. 75, 78, and 79 are also very similar to those shown in the pressure experiments. Figs. 76 and 77 represent eggs which were pressed between glass plates, whereas all the other eggs shown on Plate XLVIII were subjected to the electric current between graphite plates.

Many of the eggs used in these experiments were killed and their membranes dissolved; others, on the other hand, developed normally. The earlier stages of cleavage usually suffered much more than the later ones. In general, the most characteristic effect of the current is found in the massing of chromatin within the nuclear vesicle, as in synapsis, or in the failure of the daughter nuclei to become vesicular. Indeed the latter may remain perfectly dense spheres. In some cases, the polarity of the egg or of the cleavage cells seems to be lost and the usual sharp separation between yolk and cytoplasm disappears. Sometimes the direction of the spindle is abnormal. The eggs shown in figs. 80–93, Plate XLIX, illustrate some of the most common abnormalities observed in eggs subjected to the electric current. In all of these eggs, the boundaries between cytoplasm and yolk are but faintly marked; the nuclear membranes are usually very thin or altogether lacking and the chromatin is massed within the nucleus or scattered in clumps through the cytoplasm where it dissolves and disappears, figs. 80–86. In some cases tetrasters are present (fig. 87), but these are probably due to other causes than the electric current. In a few instances, chromosomes have entirely disappeared probably by solution, from the amphiaster leaving the achromatic parts of the latter quite perfect (fig. 90); in other cases, the achromatic part of the amphiaster as well as the chromosomes may be undergoing solution (figs. 86, 91, 92). Figs. 91 and 92 show eggs in which the position and the direction of the mitotic figures are abnormal. Finally, one frequently finds eggs like fig. 93, in which the micromeres no longer form a flat plate of cells covering over the macromeres, but rounded and irregularly scattered cells. Such conditions, which are probably the same as those named *framboisia* by Roux, are not limited to eggs treated with the electric current but may be found in almost all cases of abnormality appearing in the later cleavage and they probably represent the rounding up and separation of micromeres which were formed normally.

The abnormalities shown in Plates XLVIII and XLIX represent the principal types of abnormalities found among eggs which have been subjected to the electric

current. Among the many thousands of eggs so treated very few show any trace of modification of the structure or orientation of the amphiaster. Where the current is strong enough to produce any modification in the structure or orientation of the mitotic figure it is usually strong enough to dislocate yolk, cytoplasm and resting nuclei, as well as entire amphiasters, and to kill the eggs. In such gross changes entire spindles, centrosomes as well as chromosomes, are carried toward one pole, which judging by the work of Lillie, Pentimalli and McClendon is the anode. *In these experiments there is no indication whatever that the poles of the spindle bear electric charges differing in sign from the chromosomes nor that the spindle fibres or astral radiations represent lines or chains of force between differently charged poles.* If the forces which are at work in the amphiaster are electric, this could scarcely be the case, and it seems probable therefore that the so-called "mitokinetic" force is not electric.

On the other hand I find evidence that the spindle fibres are composed of relatively tough material and that they may be bent, distorted or displaced by centrifugal force from their normal positions without losing their identity. In this regard my results differ from those of F. R. Lillie (1909) and agree with those of Morgan (1910). Furthermore I find that the chromatic sap of the nucleus forms the interfilar substance of the spindle and escapes, when the nuclear membrane dissolves opposite the centrosomes, into the areas around the centrosomes, and that it radiates from these areas and from the entire spindle into the cell body by a process which resembles protoplasmic flowing in amœboid cells. By treatment with various chemical reagents, as well as with electricity or increased temperature this flowing may be stopped and the processes or radiations withdrawn into the central mass of archiplasm (hyaloplasm and chromatic sap). The astral radiations are therefore expressions of diffusion streams, rather than of electric lines of force. Of course it is probable that there is a difference of potential between the electric charges carried by the particles of this chromatic sap, and the colloidal particles of the cell body, but it also seems probable that the spindle figure and its radiations are due in the first instance to the escape and diffusion of nuclear substances into the cell body, rather than to the electric potentials of these substances.

Whenever two or more astral systems are present the chromosomes at first take up positions between them. Between two such centers the chromosomes form a rectilinear equatorial plate, and when many centers are present the area around each is bounded by a line of chromosomes, the whole forming a complicated pattern of hexagonal or polygonal areas, each inclosing a centrosome and bounded by chromosomes. Such a condition would be produced if centrosomes and chromosomes carried like charges, as Lillie maintains. This condition is followed quickly by a stage in which the daughter chromosomes separate from one another, and, as daughter plates, approach the centrosomes. This movement might, conceivably, be due to the daughter chromosomes carrying like charges and consequently repelling each other; however there is, on this hypothesis, no

apparent reason why chromosomes are drawn together at the poles of a bipolar figure, on the other hand they should repel one another and thus be scattered through the cell in positions of equilibrium between the poles and the other chromosomes.

In conclusion, I do not find that the phenomena of spindle formation nor of chromosomal movement can be consistently explained by Lillie's or Gallardo's hypotheses. I find no evidence in favor of these hypotheses in experiments in which an electric current is passed through dividing cells. On the other hand I find abundant evidence in all my experiments that the phenomena of karyokinesis and also of cytokinesis are associated with diffusion phenomena between nucleus, centrosome and cell body.

V. Effects of Abnormal Temperature.

(Plate L. Exps. 960–961, 1170–1177.)

Many experiments have been made on the influence of temperature on development; among more recent investigations those of Driesch (1893), O. Hertwig (1890), Delage (1901), Greeley (1902), Schücking (1903), R. Lillie (1908) on echinoderms, and of Rauber (1883), O. Hertwig (1896), O. Schultze (1894, 1899), Lillie and Knowlton (1897), Bataillon (1903) on amphibians, must be mentioned. Of work which deals primarily with the influence of altered temperature on cell structure and division, the most important is that of O. and R. Hertwig (1887), who found in the sea urchin egg that a large increase of temperature led to polyspermy, suppression of astral rays, even those in connection with the sperm nucleus, lack of growth on the part of the sperm nucleus, eccentricity of first cleavage spindle and unequal cleavage (*Knospenfurchung*). Driesch (1893) found that increased temperature led to a reduction of the surface tension of the blastomeres of sea urchin eggs, to more or less separation between the blastomeres and to suppression of micromere formation. Sometimes the blastomeres of the 8–16 cell stages separated into two groups, thus forming twins. If the temperature were increased during gastrulation, exogastrulae resulted. O. Hertwig (1896) found that increased, as well as decreased, temperature led to the suppression of cleavage and development at the vegetal pole of the frog's egg.

The influence of decreased temperature on eggs has been studied by O. Hertwig (1890) who found in sea urchin eggs that a temperature of 2° to 3° C. for a half hour led to the formation of a large reception cone; if the eggs were then warmed, a high degree of polyspermy resulted. Cold caused the disappearance of astral rays, which quickly reappeared on warming; it also caused the degeneration and complete disappearance of the first cleavage spindle and of the polar rays, while the chromatic part of the amphiaster remained unaltered; when such eggs are warmed, the spindles and polar rays appear again and division is completed normally. By long action of cold the chromosomes are affected and form a reticular or vesicular nucleus. Morgan found that segmentation might be started in unfertilized eggs of *Arbacia* by freezing the water in which they

were placed. Sala (1893) and Zur Strassen (1898) found that the eggs of *Ascaris megalocephala* might be caused to fuse together by cooling them to 3° to 4° C.

My own work on the influence of altered temperature on the cleavage processes of *Crepidula* are limited to ten experiments,—nine on the effects of increased and one on the effects of decreased temperature. At the time the experiments were made the normal summer temperature of the sea water at Wood's Hole was about 22° C.; however the temperature of the water in the finger bowls in which the eggs were developing normally, varied from 22° to 27°.

In the experiments with increased temperature the eggs were taken from finger bowls at room temperature, in which the thermometer registered from 22° to 27°, and were put into sea water varying in the different experiments from 33° to 38° C. They were kept in the warm water from ¼ hr. to 4 hrs.; some of the eggs were then fixed at once, while others were put back into the finger bowls in water which varied with the room temperature from about 22° to 27°, where they were left for periods of time varying from 3 hrs. to 15 hrs. The records of each of the experiments are given in the catalogue at the end of this paper.

The eggs thus treated showed many notable changes in structure,—indeed in no other experiments recorded in this paper were the modifications so great and so interesting. That these modifications are not due merely to heat coagulation is shown by the partial or complete recovery of the eggs when returned to normal conditions. However owing to the relatively small number of experiments, I have not been able to analyze these modifications as thoroughly as could be wished. This I hope to do in a later paper, as I am now engaged in extending these experiments.

In the experiments with altered temperature, as in all the others, the greatest changes are produced when the eggs are in some phase of kinesis at the beginning of the experiment, while stages of interkinesis are affected relatively little. The early stages, also, are more affected than the later ones. The most general results of increased temperature are: (1) Reduction of surface tension and consequent irregularities in the outlines of the eggs; owing to local reductions of surface tension the type of polar-body formation or of cleavage may be greatly changed (figs. 94, 95). (2) Segregation of archiplasm (hyaloplasm and chromatic nuclear sap) into distinct areas, separate from the clearer plasma (enchylema); withdrawal of the archiplasm of the astral radiations into the central areas of the aster and into the division walls between cells (figs. 94–99). (3) Profound changes in the orientation and structure of the mitotic figures; loss of all spindle fibers and centrosomes; scattering of chromosomes, which are often thrown entirely outside the mitotic figures and even outside the cytoplasmic areas (figs. 97–99). (4) Formation of numerous karyomeres from these scattered chromosomes; indeed by slight increase of temperature almost every chromosome may be caused to remain distinct from every other one, and to give rise to a separate chromosomal vesicle.

Only one experiment was made on the effects of decreased temperature on

the cleavage processes in the eggs of *Crepidula*. In this experiment, dishes of sea water containing eggs in early cleavage stages (1–8 cells) were placed on ice in a refrigerator for from 4 to 40 hours, and were then fixed at once after removal from the refrigerator. The temperature of the water in the dishes was a little above 2° C. Figures 100–102 represent eggs which were on ice 16 hours; figures 103–105, eggs which were on ice 40 hours. Cleavage in these eggs was greatly delayed if not entirely stopped; after 40 hours on ice many of the eggs were still in the 4-cell stage. Spindle fibers and astral rays were present, though perhaps less distinct than in normal eggs.

The most characteristic feature of eggs which have been on ice from 4 to 16 hours is the great distinctness of the spheres which, in resting stages, appear to be bounded by a definite membrane (fig. 101), and which stain so deeply that they look very much like nuclei. In division stages, the spheres are surrounded by coarse, chromatic granules, the sphere granules (S. G., fig. 100 *et seq.*), which are possibly homologous with mitochondria. In the eggs which were 40 hours on ice, the spheres have lost their distinctness and in their places are masses of coarse sphere granules (figs. 103–105). Apparently the centrosomes in the resting stages have also disappeared and further experiments are necessary to determine whether they also have broken up into granules.

VI. Effects of Ether.

(Exps. 800–803, 818–819, 877–878, 1180, 1181.)

In order to test the effects of anæsthetics on the kinetic phenomena of cell division, varying quantities of ether were added to sea water in which eggs were placed. With a small quantity of ether acting for a short time no effect was noticeable. Thus ½ per cent. to 1 per cent. of ether acting for ½ hr. to 1 hr. produced no visible changes. However ½ per cent. acting for 24 hours caused the nuclei to become more densely chromatic and the spindle fibers and astral rays of the mitotic figure to disappear. 1 per cent. acting 5½ hrs. or even for 16 hrs. caused very few if any changes; the distribution of cytoplasm and yolk, and the character of nuclei and centrosomes, whether in rest or division, are apparently normal. However 1 per cent. acting for 25 hrs. produces many changes; in some cases the cleavage is very irregular and the chromatin is clumped in the resting nuclei. In division stages, many chromosomes are scattered and clumped. Nevertheless spindles and spindle fibers are present and are apparently normal in structure and function. On the other hand 3 per cent. ether acting for ¼ hr. produced profound changes in the distribution of yolk and cytoplasm. The cytoplasm is intermingled with the yolk and *vice versa*, and cytoplasm is carried in along the whole cleavage plane between macromeres. The chromosomes in mitosis are often scattered along the spindle, the spindle fibers have disappeared, and telokinetic movements are stopped. When 3 per cent. ether was allowed to act for 3 hrs. and the eggs were then placed in normal sea water

for 6 hrs., the results are the same as in the preceding experiment, except that large sphere granules are present and are scattered through the cell and surround the nuclei. Chromatin is clumped within the resting nuclei; chromosomes are also clumped in the spindles. Centrosomes, spindle fibers and astral rays may be present, but mitosis is very irregular, polyasters often being present; in other eggs spindle fibers and astral rays disappear. These results are, in general, similar to those obtained by Gerassimoff (1892), on *Spirogyra*, and by Häcker (1900) and Schiller (1909) on the segmenting eggs of *Cyclops;* in all of these cases the spindle fibers were caused to disappear by the use of ether, but whereas these authors observed that the division continued by a kind of amitosis after the disappearance of the spindle, I have seen no evidence of real amitotic division in *Crepidula*. Irregularities in the movements of the chromosomes with the consequent scattering of chromosomes along the entire length of the mitotic figure does sometimes lead to a chromatic connection between daughter nuclei. Such modified mitoses, which are suggestive of amitosis, are found in many of these experiments and are described more fully on pages 535, 548, 550 and 557.

VII. Effects of Decreased Oxygen Tension.

(Plate LI.)

In view of the fact that the centrosomes and the surrounding spheres move regularly during telokinesis to a free surface of the cell where the sphere substance spreads out under the cell membrane, it seemed desirable to determine whether this movement is due to oxidations at the surface of the cell and consequently to the presence of free oxygen in the surrounding water. Accordingly, the oxygen tension of the water was reduced in two ways, first by boiling the water in flasks or test tubes to drive off contained gases, after which the tubes were stoppered and cooled before the eggs were placed in them, second by running a current of purified hydrogen gas through a series of wash bottles in which eggs were placed.

1. *Boiled Sea Water.*

(Figs. 106–109, 112–114, 116. Exps. 935–940, 947–953, 1010–1022.)

Pure sea water was boiled vigorously for a few minutes in order to drive off contained gases, but not so much as to lead to any appreciable concentration of the salts. Flasks or test tubes of this water were carefully closed with rubber stoppers which dipped into the water and consequently left no air space in the tubes. The water was then cooled to the temperature of the water in the aquaria and the eggs were gently introduced into the tubes. In thirteen experiments of this kind (Nos. 935–940, 947–953) the tubes were left unstoppered and eggs in stages varying from 1 cell to 24 cells were put into the tubes and left in them for periods varying from 4 to 48 hours. Eggs which had been 48 hours in the boiled water were generally becoming abnormal and some of them were dead, but all eggs which were in the tubes from 12 to 24 hours were normal in form, or nearly

so, though development had been much retarded. In twelve other experiments (1010–1022), in which the tubes were carefully stoppered after the eggs were introduced, development was not only retarded but, in many cases, completely stopped. In these eggs, nuclei and nucleoli are larger than usual, which may be explained by the duration of the resting stage (interkinesis). The chromatin within the resting nucleus is usually clumped into a nucleolus-like mass and the spheres have lost their definite outlines and consist of large, scattered granules (figs. 106–109, 112–114). Mitosis may be halted at any stage for an indefinite period, the spindles and chromosomes remaining distinct, while the centrosomes become larger than normal and the polar rays grow indistinct and finally disappear entirely (figs. 107, 109). When mitosis has been halted for a long time, as in the egg shown in fig. 116 which was in a stoppered tube of boiled sea water for 48 hours, the spindles shrink in size and stain deeply, while the chromosomes form a distinct ring around the spindle.

2. *Atmosphere of Hydrogen.*

(Figs. 110, 111, 115, 117, 118. Exps. 879–883, 1023–1029.)

Hydrogen was generated in the well known Kipp apparatus and a stream of the gas, after being purified and washed, was allowed to bubble through the sea water in a flask containing the eggs to be studied. In this way, most of the air in the water and flask is replaced in a short time by hydrogen.

The first effect of such treatment is a slowing of division; after 4½ hours, there were 1-cell and 2-cell stages present in the flask, whereas in the control all the eggs had passed beyond these stages; after 7½ hours, there were many 1-cell to 4-cell stages present in the flask, whereas in the control all had reached the 24-cell stage. Development in an atmosphere of hydrogen is normal as far as it goes; the direction, size and quality of cell division and the direction of movement in telokinesis are not affected, but it is quite evident that after a short time the eggs cease altogether to develop in an atmosphere of hydrogen. In another experiment (No. 1023), hydrogen was allowed to bubble for 2 hours through a wash bottle containing eggs and the bottle was then left open to the air for 2 hours. Most of these eggs appeared quite normal, though a few showed swollen nuclei; however, development had been stopped. In other experiments (Nos. 1024–1026), hydrogen was run through bottles containing eggs for 1 or 2 hours and the bottles were then stoppered and the eggs left in them for 3, 5, 18, or 20 hours. When the eggs were in an early stage at the time of the experiment, development was stopped; in one case (No. 1026), where the eggs were in an advanced stage of cleavage when the experiment began, development progressed normally until normal gastrulæ were formed 20 hours after. This one experiment indicates, what many others prove, that the early stages of cleavage are much more sensitive to environmental changes than are the later ones. In all cases in which development is stopped for some time, nuclei and nucleoli become

much larger than normal, and the spheres and centrosomes consist of large, scattered granules; if the development has been halted during mitosis, the spindles, centrosomes, and chromosomes remain distinct but the polar rays disappear, being drawn into the central portion of the amphiaster (figs. 110, 111, 115, 117). If development has been stopped for many hours (18–48 hours), cytoplasm may move toward the vegetal pole along the first and second cleavage planes (fig. 116), while in other cases yolk may appear around the centrosomes nearest the animal pole (fig. 118).

Finally, by the aid of Dr. A. P. Mathews, I was able to employ in certain experiments (Nos. 1027–1029), atmospheres composed of known quantities of air and hydrogen. In one case (No. 1027), the proportions were 60 vols. of hydrogen to 40 vols. of air; in two others (No. 1028, 1029), the proportions were 70 vols. of hydrogen to 30 vols. of air. In all of these experiments development was stopped within a few cleavages, though the eggs remained in the bottles from 12 to 24 hours.

To sum up, it may be said that the first effect of reduced oxygen tension is the slowing of development and of cell division, and as a result of this retardation, the resting nuclei, which continue to imbibe materials from the cytoplasm, become very large and achromatic; at the same time, the nucleoli grow larger than normal, as is always the case when the resting period is prolonged. The nuclei and nucleoli thus come to resemble the germinal vesicle and germinal spot of immature egg cells, and I believe that this resemblance is a real, and not merely an apparent one. The spheres of resting stages also lose their definite outlines and are resolved into large granules which are more or less scattered. In division stages, mitotic figures may persist for many hours (18–48 hrs.); the spindle fibers remain distinct and the spindle may shrink and at the same time stain more deeply than normally; the polar radiations disappear and the centrosomes frequently enlarge. Later stages of cleavage are not as much affected as are earlier stages.

In all cases where the experiment has not been prolonged more than 24 hours, when eggs are returned to normal sea water development is resumed and the nuclei and cells become normal in appearance. In some cases the micromeres cease to form a one-layered epithelium, and become individually rounded; collectively, they form a mass more than one cell thick, as I reported in a former paper (1902, p. 102). Later work has shown that this result is exceptional rather than usual, and that it occurs in many other experiments in which eggs are degenerating (*framboisia* of Roux).

I conclude therefore that the presence of oxygen in the medium is not the chief cause of the movements of telokinesis.

VIII. Effects of Carbonic Acid.

(Plate LII. Exps. 1163–1169, 1169a, 1169b.)

Carbonic acid was first employed by Delage (1902) to produce artificial parthenogenesis in starfish eggs, and it has since been employed by many other investigators for this purpose. A cytological study of its effects on eggs has been made by Godlewski (1908). Loeb (1906) and Godlewski (1908) found that membrane formation in unfertilized echinoderm eggs could be called forth by this substance. Godlewski observed that in CO_2 solutions parthenogenetic mitoses are not preceded by nuclear growth, and that in strong CO_2 solutions fertilized eggs rarely segment, though nuclei may continue to divide, thus giving rise to cells with many nuclei. Later these nuclei may fuse together producing synkaryonts (Strasburger, 1907), which may subsequently divide by bipolar or multipolar mitoses; the size of the plasma field which subsequently cuts off around such nuclei is proportional to the size of the nuclei.

Only a few experiments were tried to learn the effects of carbonic acid on the cleavage processes in *Crepidula* but they yielded some very interesting results, and they call for an extension of these experiments.

Normal sea water was charged with CO_2 in the well-known "sparklet siphon" bottle, and equal parts of this charged sea water and normal sea water were poured over the eggs in finger bowls, which were loosely covered. The eggs were left in this water for from 7 to 42 hours, and were then fixed, stained, and mounted.

A large number of the eggs so treated are abnormal and some of these abnormalities are highly characteristic. Among these may be mentioned the following: All cell membranes appear unusually heavy and chromatic so that the outlines of the cells are extraordinarily distinct, at the same time these membranes are often wrinkled or separated from the cell substance (figs. 119, 130 *memb.*) and on many of the cells there are lobes, bridges, and threads (figs. 127, 130, *L*). comparable to those observed by Andrews (1898) in the so-called "spinning phenomena." The cleavage of the yolk may be entirely or partially suppressed, a phenomenon which is of frequent occurrence in many other experiments, while the cleavage of the protoplasmic part of the egg goes on in more or less normal manner. Thus in figs. 119–121, the cleavage of the yolk is entirely suppressed but several "micromeres," some of them with several nuclei and spheres, have been formed at the protoplasmic pole. In fig. 122, which has an abnormally large second polar body, the first cleavage spindle has divided the nuclei in a normal manner, but the cleavage furrow has cut down through the protoplasm into the yolk and there stopped in a "cleavage head" (Ziegler, 1903), such as is found in the cleavage of the eggs of many cœlenterates. In no other preparations of *Crepidula* eggs have I found such a type of cleavage as this and it would be interesting to learn whether this cœlenterate type could be produced in other eggs by the use of CO_2. The area marked *S* in the yolk of fig. 122 may be a sphere or "cytaster."

Cases of the suppression of yolk cleavage, with interesting results, are shown in figs. 123, 125, 126, 127, 128, 129. In figs. 123, 128, and 129, the macromere *AB* did not divide at the second cleavage, though its nucleus did. In fig. 123, the first micromere (1*ab*) formed from this undivided macromere is abnormal, all the other micromeres being normal. In fig. 125, the half of the second cleavage furrow between *C* and *D* was suppressed, while the half between *A* and *B* was abnormal in position giving rise to a large macromere *A* and a small macromere *B*, lying above *C* and *D*. Each of these macromeres has given rise to a micromere which is normal in size and appearance, though 1*c* is abnormal in position. In fig. 128, the second cleavage furrow was suppressed in both of the first two blastomeres, and at the third cleavage the two mitotic figures in each blastomere came so near each other at one pole that triasters were formed, with the result that each double macromere gave off a single micromere of the first set (1*ab*, 1*cd*), each with two or more nuclei and spheres. At the fourth cleavage, the two spindles in each macromere were distinct, one of them being directed dexiotropically, the other læotropically, and as the result of this cleavage each double macromere gave off two separate micromeres (2*a*, 2*b*, 2*c*, 2*d*), the two lying on opposite sides of the first micromere. In fig. 129, all the micromeres of the 24-cell stage are present and all are approximately normal. The fact that two nuclei may exist within the same cell and may divide in normal fashion giving rise to typical micromeres is thus plainly demonstrated. Where abnormal micromeres arise from such binucleate macromeres, it is usually due to the fact that the two mitotic figures lie so near each other that triasters or tetrasters are formed. One interesting fact brought out in this, and in other experiments, is that when the nucleus of a cell divides and the cell body does not, the two nuclei usually take up positions at opposite sides of the cell, and in subsequent divisions of these nuclei the direction of division is frequently dexiotropic in one and læotropic in the other, whereas in normal cleavage the position of the resting nuclei and the direction of division is dexiotropic or læotropic in both. In fig. 123, the nuclei 2*A* and 2*B* lie at opposite sides of the macromere, though the cleavages by which 2*a* and 2*b* were formed were not exactly at right angles to each other. In fig. 128, the direction of division in forming 2*a* and 2*c* is læotropic, in forming 2*b* and 2*d* it is dexiotropic. In fig. 129, the direction of division in forming 3*a* was læotropic, in forming 3*b*, dexiotropic. Fig. 131 represents an egg in which the direction of division in one of the first two blastomeres was at right angles to that in the other with the result that a T-shaped cleavage mass was formed. Each of the four macromeres has given rise in typical manner to three sets of micromeres and the first and second sets have subdivided, as they do in normal eggs, but the relation of these micromeres to one another is quite atypical, the micromeres being arranged in sets of three over the three contiguous macromeres, while the micromeres from the displaced macromere *D* are applied to one side of this three-cornered micromere plate.

The other figures shown on Plate LII are more abnormal than the ones just

described and are more difficult of interpretation. In fig. 124, three macromeres were formed in a row, the one farthest to the right being approximately normal; it contains one nucleus and sphere and has given off two micromeres, the first of which was formed lævotropically and is now dividing, and the second is just coming off dexiotropically. The middle macromere contained a polyaster and gave off a large micromere with three nuclei, adjoining the polar bodies, and it now shows a polyaster in its second cleavage (fourth general cleavage). The macromere to the left contains a perfect achromatic spindle but no trace of chromatin; evidently a centrosome without a nucleus went into this macromere at the second cleavage, while the middle macromere received two or more nuclei and centrosomes.

A somewhat similar case is found in fig. 126; there are here three macromeres, one of which (right) contains an amphiaster and a triaster and has just given off two micromeres of the second set on opposite sides of the large micromere of the first set which was formed at the previous cleavage; another macromere (left) has just given off in dexiotropic direction a micromere of the second set, while the micromere of the first set which was formed from this macromere at the previous cleavage is now dividing and contains two centrosome and two equatorial plates; the third macromere (above) contains several centrosomes and spheres but no trace of nuclear material.

Figs. 127 and 130 show two very irregular cleavage forms, in which the cell membranes bulge out irregularly in lobes or threads; even the polar bodies in fig. 127 are connected with the contiguous cells by such threads. The very irregular cleavage shown in these two figures is probably due to these abnormal surface tension phenomena, which lead to the formation of cells which are atypical in size and position.

The figures shown on Plate LII are but a few of the almost infinite variety of abnormalities which resulted from the experiments with carbonic acid. It seems to me that *these results indicate the importance of surface tension phenomena in mitosis and development, the importance of cell walls in preventing the interference of one mitotic system with another, and the connection between localized reductions in surface tension and the direction and position of mitotic spindles.*

IX. Effects of Diluted Sea Water.

(Plates LIII, LIV. Exps. 858, 859, 870–876, 954–956, 993, 1182–1186.)

In testing the action of various changes in the environment on nuclear and cell division in *Crepidula*, a number of different experiments were made on the effects of diluted sea water. In the case of animals living in shallow water along shore, as *Crepidula* and its messmate *Pagurus* do, it must frequently happen that the density of the sea water is much reduced by heavy rains or by streams of fresh water. Do these eggs show an adaptation to such conditions? I found that a dilution of ¼ or ½ part fresh water to 1 part sea water produced little if any

effect on the eggs of *Crepidula*. However, when equal parts of fresh water and sea water were used, many modifications were produced. Almost all of the experiments enumerated above were made with a dilution of equal parts of fresh water from the tap and of the normal sea water supplied to the aquaria at Wood's Hole. In three of the experiments, viz., Nos. 859, 875, 876, 100 c.c. of fresh water were added to 50 c.c. of normal sea water. The eggs were left in the diluted sea water for lengths of time varying from ½ hour to 7½ hours and were either fixed at once or put back into normal sea water for periods varying from ½ hour to 52 hours.

Driesch (1893) found that sea urchin eggs did not segment in 30 parts normal sea water and 20 parts distilled water, though the nuclei continued to divide. Loeb (1895[1]) was able by means of diluted sea water to cause the egg membrane of the *Arbacia* egg to burst and a portion of the egg to flow out, and from such eggs double embryos developed. Schücking (1903) caused artificial parthenogenesis in *Asterias* by the use of distilled water.

The first effect of the diluted sea water on the eggs of *Crepidula* is to cause a slight swelling of the cells and to render all cell membranes very indistinct. Indeed the outlines of eggs become hazy and the macromeres sometimes separate from one another more or less completely. In all cases where eggs in dilute sea water are crowded together, they lose their individual outlines and apparently fuse together. If the diluted sea water is allowed to act for a long time or if the dilution is great (2 : 1), the cell membranes may burst. Even in extreme cases, however, the swelling of the eggs in diluted sea water is not great; when fixed and mounted the diameter of the normal egg after fertilization and before cleavage is about 136–140μ. The swollen egg rarely measures more than 144μ. After the eggs have been returned to normal sea water they again shrink to normal size, and cell membranes become normal in appearance.

The eggs shown in figs. 132–135, 137–140, 144, were placed for ½ hr. in sea water diluted with two volumes of fresh water, and were then left in normal sea water for 7 hrs. All other eggs figured on Plates LIII and LIV were treated with sea water to which was added equal parts of fresh water.

In all of these eggs, development has been delayed more or less. Eggs which were put into diluted sea water during maturation stages are frequently polyspermic (figs. 132–134); the supernumerary sperm nuclei are evidently undergoing degeneration, since they are homogeneous and stain faintly.

In considering the effects of diluted sea water on cell division, the effects on the division of the cell body will be considered first, and then the effects on mitosis. In figs. 132–135 and 145–148 division of the yolk has been completely suppressed; a very large second polar body is shown in fig. 134, and various stages in the cleavage of the protoplasmic portion of the egg are shown in figs. 145–148. The arrangement of the micromeres in the figures last named is more or less irregular, and it is not possible to tell whether three micromeres were separated from the single large macromere in sets of one, or whether the micromeres were separated from the macromere in sets of two or more. Since polyasters were present in

many cleavages of the macromere, it is not probable that the cleavages are entirely comparable to those of normal eggs.

If the first cleavage had already occurred when the eggs were put into diluted sea water, the yolk may fail to divide in the second cleavage, so that only two macromeres are present throughout the later development (figs. 137–139, 149, 150, 157), or one of the macromeres may divide and develop normally, while the other remains undivided (fig. 140). In these cases each macromere may give off micromeres in more or less normal fashion; thus one micromere of the first set is formed from each of the macromeres in figs. 137–139, and these micromeres are apparently normal in structure and position, though the macromeres from which they came contain polyasters or multiple nuclei. However in the more advanced stages of such eggs, shown in figs. 149, 150, the micromeres of the different sets cannot be identified with certainty.

In most of the eggs in which cleavage furrows have been suppressed, polyasters and multiple nuclei are present, and in many instances these are undoubtedly due to the interference of two mitotic systems, originally independent. Sometimes, however, the two mitotic systems within a single cell remain independent and give rise to micromeres which are in the main normal. Thus in figs. 157–158 the macromeres did not divide at the second cleavage, though the nuclei did. These nuclei and their mitotic figures have remained distinct and have given rise to a cap of ectomeres, which are nearly normal, though frequently the divisions by which they were formed have been bilateral rather than spiral; thus in fig. 157 the two spindles in the one macromere, which are labeled 4*C* and 4*D*, are bilaterally arranged. Both figs. 157 and 158 show that the fourth quartet cells 4*c* and 4*d* are formed simultaneously from the macromere *CD*, whereas, in the normal egg, 4*d* is formed at the 24-cell stage and 4*c* at the 52-cell stage. *The fact that the two nuclei are in the same cell has led to the synchronizing of two divisions, which are separated by a considerable space of time when these nuclei are in separate blastomeres.* Furthermore the size and structure of these cells, 4*c* and 4*d*, are alike and it is probable that both are mesentoblasts, whereas in normal eggs 4*d* is relatively small and rich in protoplasm and is the one and only mesentoblast while 4*c* is large and rich in yolk and is an entoblast. *In the absence of a division wall between C and D the typical differentiations which arise between these cells and their progeny cannot develop.*

But while the yolk cleavage is frequently suppressed in eggs treated with diluted sea water, it is sometimes, apparently, increased, since eggs may be found with more than four macromeres (figs. 143, 156). However it is probable that this abnormality is due to pressure rather than to diluted sea water. In fig. 142 the macromeres are separated and the micromeres are crowded in between them, just as in fig. 55 of the pressure experiments. In fig. 156 it appears that the egg was subjected to pressure in the direction of the chief axis after the third cleavage and before the fourth; the first set of micromeres and their derivatives are quite normal, the second set consists of large cells filled with yolk; this egg is more or less like figs. 56, 60, 64 of the pressure experiments.

Not infrequently the blastomeres of the 2-cell or 4-cell stage are separated from one another by the action of diluted sea water, and the further development of such isolated blastomeres is similar to that which occurs when the blastomeres are isolated by shaking. Thus figs. 135, 144, 151, 155 represent various stages in the development of blastomeres isolated in the 2-cell or 4-cell stage by treatment with diluted sea water; they closely resemble figs. 33, 35 and 44, where the blastomeres were isolated by shaking. In fig. 144 the macromeres *A* and *B* were separated from *C* and *D* in the 4-cell stage; each macromere has given off a micromere of the first set, which has divided normally, and the micromeres of the second set are forming in typical fashion, except that the chromosomes are scattered along the whole length of the spindles. Fig. 151 is the half of an egg in which the second cleavage furrow was suppressed, and the method of its isolation is indicated by figs. 149, 150; in both of the latter the yolk cleavage was suppressed after the first cleavage and the two macromeres were nearly separated from each other, remaining connected only by a narrow bond; micromeres have formed from these half-isolated macromeres in more or less normal manner, though I am unable to identify them individually.

In a few instances, as shown in fig. 136, the polarity of the egg may be changed, or even reversed. In this figure a polyaster was present at the first cleavage, which was also abnormal in other respects, but the most significant abnormality is found in the position of the cytoplasm, nuclei and spheres at the side of the cells opposite the polar bodies; the polarity of these cells is reversed as compared with that of normal eggs. I am unable to explain how this condition has arisen.

Finally we may consider the effects of diluted sea water on the mitotic figures. As already noted a very common abnormality is the presence of polyasters in division stages and, as a result of this, of multiple nuclei and spheres in the resting stages. Such polyasters are, in most cases, due to the suppression of the cleavage furrow and to the subsequent interference of amphiasters, originally independent.

Another abnormality of mitosis which is so common in these experiments as to be very characteristic of them, is the scattering of chromosomes along the length of the spindle, and general irregularity in the separation of chromosomes toward the poles of the spindle. Even in amphiasters which are otherwise normal the chromosomes show this irregular distribution (figs. 140, 144, 153) and of course it appears also in polyasters (figs. 135, 137, 138, 139, 147, 152). Frequently a part of the chromosomes are never drawn to the poles of the spindle, but are scattered along the connecting fibers, and when the chromosomes which have reached the poles unite to form daughter nuclei, the scattered chromosomes form a chromatic strand connecting the nuclei (figs. 141, 143, 152, 154). In many instances this chromatic connection between the daughter nuclei is strongly suggestive of amitosis (figs. 141, 143, 152, 154), although there is no doubt that it is produced in the manner stated. Similar chromatic connections between daughter nuclei, due to the scattering of chromosomes along the length of the

spindle, are found in many other experiments,—indeed this is one of the most common modifications of mitosis. This phenomenon and its significance will be considered further in the final section of this paper, pp. 550–553, 557–559.

X. Effects of Hypertonic Sea Water.

(Plates LV–LIX.)

NaCl added to sea water: Figs. 159–172, 182–192, 202–207, 209–213, 217, 220–223. Exps. 804–816, 821–832, 839–840, 843–844, 861–865, 965–990, 994, 1187.

$MgCl_2$ added to sea water: Figs. 197–200, 208, 214–216, 218, 219. Exps. 833–835, 841, 842, 845, 846, 866–868, 991, 992.

KCl added to sea water: Figs. 173, 193, 194. Exps. 836–838, 847, 847*a*.

Sugar added to sea water: Exp. 869.

Herbst's Ca-free sea water: Fig. 201. Exp. 848.[1]

The effects of hypertonic sea water upon cell division have been studied by a large number of investigators, particularly since Loeb's (1900) epoch-making discovery that artificial parthenogenesis could be induced in sea-urchin eggs by this means. Among the more important works in this field must be mentioned those of O. and R. Hertwig (1887), J. Loeb (1892, 1895[2], *et seq.*), Morgan (1894, 1896, 1899, 1900), Norman (1896), Driesch (1892, 1895), Herbst (1895, 1900), Wilson (1901, 1901[1]), Lillie (1901, 1905), Bataillon (1901, 1904), Scott (1906), Treadwell (1902), Lefevre (1907), Kostanecki (1904, 1906, 1908), Konopacki (1911), *et al.* All of the authors named found that hypertonic solutions led to a retardation or cessation of cell division, while almost all observers have agreed that nuclear and centrosomal divisions may go on after division of the plasma has ceased. Morgan finds that the most characteristic effect of hypertonic sea water is the production of astrospheres, which may appear in large numbers and subsequently fuse together into a few very large ones. He concludes that there is a definite substance (cyanoplasm) which forms the astrospheres, and that if cell division is delayed by hypertonic solutions this cyanoplasm may accumulate to form one or two suns or astrospheres.

Loeb (1906) supposes that hypertonic solutions act first in a physical way on the plasma by osmotically removing water from the egg and thus preventing cell division, without necessarily affecting the chemical processes by which nuclein is synthesized from constituents of the plasma. In such eggs chromatin may grow, chromosomes may form and divide, and astrospheres may develop, while streaming and contractility of the plasma is interrupted and cell division is stopped. With higher concentration of salts the chemical processes may also be brought to a standstill.

Further references to the literature of this subject will be made in connection with the various effects produced on the eggs of *Crepidula* by hypertonic solutions,

[1] This is classified under hypertonic solutions because its effect on cell division was similar to that of a hypertonic solution.

but I must not fail to call attention at this place to the many general resemblances between my work and that of Konopacki (1911).

In the course of this work 79 separate experiments were made on the effects of hypertonic sea water on cell division in the eggs of *Crepidula*. In 60 of these experiments the sea water was rendered hypertonic by the addition of NaCl in varying quantities; in the remaining experiments $MgCl_2$, KCl, or cane sugar were added to sea water. In all cases percentage solutions were used. After having been subjected to the action of these solutions for varying lengths of time the eggs were either fixed at once or were placed in normal sea water for a longer or shorter period before being fixed. All the eggs used in each experiment were stained and mounted, and most of them were studied, though not one in a thousand are represented in the drawings.

The results obtained in any given experiment may be extremely varied, depending to a considerable extent upon the general stage of development of the eggs, and upon their precise stage in the cycle of cell division at the time the eggs were put into the salt solution. Early stages of development are always more susceptible to any kind of environmental change than are later ones; and stages during kinesis are much more susceptible than are those during interkinesis. In particular the first and second cleavages are most easily modified and seem to be especially unstable.

My observations confirm the conclusions of Loeb and others that there is nothing specific in the action of any one of the salts named; where all other conditions are similar, essentially the same results are obtained, whatever salt is used. Therefore the results of these experiments will be described under the types of abnormalities produced rather than under the particular salts employed. With different salts, different strengths of solution are necessary to produce similar results. In ½ per cent. NaCl and 1 per cent. $MgCl_2$ all division goes on slowly, but typically (Exps. 861, 866); while ½ per cent. KCl (Exp. 847) produces certain abnormalities. In 1 per cent. NaCl (Exps. 804, 808, 988, 989, 994), ¾ per cent. KCl (Exp. 836), and 2 per cent. $MgCl_2$ (Exps. 833, 841) yolk division is stopped, especially in the first and second cleavages, while centrosomal, nuclear and cytoplasmic division may proceed slowly and more or less atypically. In 2 per cent. NaCl (Exps. 805, 809, 969, 970), 1 per cent. KCl (Exp. 837), 4 per cent. $MgCl_2$ (Exps. 842, 846) all division, nuclear as well as cytoplasmic, ceases while the eggs are in the solutions, and if left in these solutions for approximately 9 hrs. this stoppage of all divisional phenomena is permanent, even when the eggs are returned to normal sea water, although the eggs may remain alive and the nuclei may continue to grow in size.

Morgan (1899) discovered that weak solutions acting for a long time are similar in effect to strong solutions acting for a short time. My work confirms this conclusion, but only in cases where the solutions are strong enough to inhibit all divisional phenomena during the time the eggs are in the salt solutions. *If solutions are weak enough to allow any of the parts of a cell to divide, the time of*

action becomes a very important factor. For this reason a weak solution acting for a long time leads to the greatest possible departures from typical development (Exps. 808, 821, 966–968, 833, 836, etc.; figs. 195, 196, 200, 208, etc.). On the other hand eggs which have been subjected to strong solutions for a short time may afterwards develop quite normally; thus in Exps. 815 and 816, 978–980, 3 per cent. and 4 per cent. NaCl acting for 1 hr. completely stop all development for the time being, but when the eggs are afterwards put into normal sea water development goes on in a typical manner; on the other hand if these solutions act for 4 hrs. or longer all cleavage is permanently stopped even though the eggs be put back into normal sea water. This fact is shown still more strikingly in Exps. 981–987 in which 5 per cent. or 6 per cent. NaCl is allowed to act for ½ to ¾ hr. after which the eggs may develop quite typically when put back into normal sea water. From these experiments it is quite evident that the injurious effects of hypertonic solutions are due primarily to their influence on kinetic rather than on static phenomena, and particularly upon the divisional phenomena of the cell. In all my experiments eggs are much more susceptible to injury during division than during rest, and when abnormalities of division are once started they rarely, if ever, right themselves. It is owing to these facts that relatively weak solutions acting for a long time (during which developmental processes proceed in abnormal directions), lead to the most extreme forms of abnormalities.

My observations on the effects of hypertonic solutions on cell division confirm the conclusions of practically all investigators who have dealt with the subject, while at the same time they contribute certain new details and interpretations. The immediate effects of hypertonic solutions on cell division fall into one or another of the following classes: (1) Suppression of yolk division without suppression of protoplasmic, nuclear, or centrosomal division. (2) Suppression of division in yolk and protoplasm, without its suppression in nucleus or centrosome. (3) Suppression of all forms of division, without stopping nuclear growth or killing the cells. This suppression of division in each of these cases may be temporary, the division starting again when the eggs are returned to normal sea water, or it may be permanent, depending upon the strength of solution used and the time of its action. In addition to these effects of hypertonic solutions on cell division the following general effects on the different parts of the cell may be noted: (4) Shrinkage of plasma, nuclei, chromatin, and mitotic figures. (5) Formation of cytasters and polyasters. (6) Irregularities in movements of chromosomes. (7) Separation of chromatin and achromatin.

1. *Suppression of Yolk Division without Suppression of Protoplasmic, Nuclear, or Centrosomal Division.*

(Figs. 159–170, 197–208, 211–216.)

In weak salt solutions (½ per cent. KCl, 1 per cent. NaCl, 2 per cent. $MgCl_2$) division of centrosomes and nuclei may proceed slowly, while division of yolk is

suppressed and cytokinetic movements and division of the protoplasm is stopped or greatly retarded. Figs. 159–170 represent eggs which were placed in 1 per cent. NaCl in sea water for 4 hrs. and were then fixed at once. In all of the eggs shown on plate LV nuclear and centrosomal division is going on, though yolk cleavage has been suppressed.

Other cases, in which cleavage has been suppressed in the yolk while still going on in the protoplasm, nuclei, and centrosomes, are shown in figs. 195–208 and 209–223. In all of these cases the eggs were subjected to a weaker solution for a long time or to a stronger solution for a short time, after which they were returned to normal sea water. In all these eggs, which are in division stages, multipolar spindles are present, which are probably the result of the interference of originally separate spindles; while multiple nuclei and spheres are present in resting stages. Cleavage is limited entirely to the protoplasmic portion of the egg, which is thus transformed from a holoblastic to a meroblastic type, and it is interesting to observe that in many cases the micromeres formed show more or less resemblance to normal micromeres. Thus in fig. 211 the spindles are in position for the formation of the first set of micromeres; in fig. 213 a first set of micromeres, normal except in number of cells and nuclei, is present, and in fig. 212 a first and second set are present, which are also normal, with the exceptions just specified. Similar tendencies to normal micromere formation, after the suppression of the first or second cleavages of the yolk, are shown in figs. 214–218, *et seq*. In all of these cases the phenomena of nuclear division are very abnormal and *the fact that micromeres may be formed in more or less normal manner in such eggs indicates that the form of cell division may be to a certain extent independent of the type of nuclear division.*

Boveri (1897) found that when the first cleavage furrow in the egg of *Echinus* is suppressed by pressure it never reappears; two cleavage nuclei are left in the undivided egg and at the second cleavage two spindles are formed, usually vertical to the axis of the first cleavage spindle and parallel to each other; the second cleavage furrow then appears as if it were the first and two cells are formed each with two nuclei, and this process is continued in later cleavages. Wilson (1901[2]), on the other hand, found that in such eggs of *Toxopneustes* the first cleavage furrow was restored after the third cleavage and sometimes even earlier. *All my observations on Crepidula indicate that when once a cleavage furrow has been suppressed and other furrows are subsequently formed, the suppressed furrow is never restored.*

2. *Suppression of Division in both Yolk and Protoplasm without its Suppression in Nucleus and Centrosome.*

(Figs. 174, 175, 183–190.)

In salt solutions of medium strength (1 per cent. KCl, 2 per cent. NaCl, 3 per cent. to 4 per cent. $MgCl_2$) cleavage of both yolk and protoplasm is

stopped in early stages, and if eggs remain in such solutions for a considerable time (9 hrs. or more) all cleavage is permanently stopped, though the nuclei may sometimes resume division when the eggs are put back into normal sea water. On the other hand if these solutions are allowed to act on eggs for a shorter time the cleavage of the protoplasm may be resumed when the eggs are returned to normal sea water (figs. 204, 207, 212, 213) but the cleavage of the yolk is permanently suppressed.

I do not find, as Loeb did, that the protoplasm in such cases begins to segment into as many cells as there are nuclei preformed; on the other hand there are usually several nuclei (or karyomeres) in each of the cells so formed. Furthermore the cleavage of the protoplasm never occurs during the resting stages of nuclei and centrosomes, but only during periods of mitosis, and there is an evident tendency for the protoplasm to segment around each of the superficially placed centrosomes (fig. 204). Only in cases where these centrosomes are very numerous or where they lie some distance from the surface are there no constrictions in the protoplasm around each astral system as a center (figs. 203, 219).

Loeb believes that the failure of plasma to divide, in hypertonic solutions, is due to the withdrawal of water from the egg. In my experiments hypotonic solutions as well as hypertonic ones cause a suppression of cell division. In the former the egg takes up water, in the latter it loses water, and it does not seem possible that diametrically opposite conditions should produce identical results. Many other conditions also lead to the suppression of cleavage, especially in the yolk,—indeed this is the one abnormality of development which is most readily produced by any change in the environment,—and it shows that in such eggs as those of *Crepidula*, holoblastic cleavage may easily be transformed into meroblastic. A study of the catalogue of these experiments given on pp. 559–576 will reveal the fact that *suppression of cleavage, especially in the yolk, may be caused by pressure, electric current, cold, ether, reduced oxygen tension, increased carbonic acid, diluted sea water and concentrated sea water. If cleavage is the result of some simple physical process, such results are difficult to understand, but if it be the result of more complex physiological processes, such as contractility or movements on the part of the plasma, then it is possible to understand how anything which weakens or disturbs this function of the plasma may cause stoppage of cell division.* When eggs are returned to normal sea water after having been subjected to hypertonic solutions the various cell constituents, if they recover their power of division, return to it in the inverse order of their suppression in the solutions, activity reappearing first in the centrosomes, then in the nuclei, then in the protoplasm and finally in the yolk.

3. *Suppression of all Forms of Division without Stopping Nuclear Growth.*

(Figs. 171–173, 176.)

In solutions of 1 per cent. KCl, 2 per cent. NaCl, or 4 per cent. $MgCl_2$ in sea water, which are allowed to act for approximately 9 hrs., or in stronger

solutions which are allowed to act for a correspondingly shorter time, all forms of division are permanently suppressed, so that when eggs subjected to such solutions are returned to normal sea water they never show any signs of division either of cytoplasm, nucleus or centrosome. Nevertheless such eggs may remain alive for several days and their nuclear vesicles may grow to enormous size. In such eggs centrosomes and spheres are usually entirely lacking, or at best are small and indistinct; the chromatin, which is always contracted into a nucleolus-like mass within the nuclear vesicle while the eggs are in these solutions, remains permanently in this condition when the eggs are returned to normal sea water, and never again assumes a reticular form, nor gives rise to chromosomes. I attribute the complete cessation of divisional activity to this inability of centrosomes and nuclei to recover their normal forms and functions.

The nuclear vesicles grow to a great size and in this condition they have all the appearances of germinal vesicles of immature eggs. One cannot fail to be impressed with the resemblance of such cells to immature egg cells, not merely in their form but also in the loss of the power of division, their low metabolic activity, and their ability to remain alive almost indefinitely while in this condition. It would be worth while to treat such eggs with some of the various reagents by which it has been found possible to stimulate immature eggs to form polar bodies, in order to see whether divisional activity might again be revived in them.

In addition to the limiting action of hypertonic solutions on the division of the cell body, the nucleus, and the centrosome, other striking results are produced which will now be described.

4. *Shrinkage of Plasma, Nuclei and Mitotic Figures in Hypertonic Solutions.*

The first effect of hypertonic solutions on the eggs of *Crepidula* is to cause a shrinkage, or contraction, of the plasma, nuclei, and mitotic figures, probably accompanied by the loss of a small amount of water from the egg, as Loeb has maintained. However since the diameter of the egg as a whole decreases very little, the loss of water must be slight. Indeed this shrinkage shows itself not so much in the decrease in size of the entire egg as in the more complete segregation of the plasma from the yolk, on the one hand, and from the more fluid inclusions (oil, water, etc.) on the other. This is accomplished, apparently, by the withdrawal of outlying portions and radiations of plasma into a central mass immediately surrounding the nucleus, while at the same time the yolk and more fluid inclusions are forced to the periphery of this mass. In this way a segregation of these three constituents of the egg is accomplished, similar in the nature of the substances segregated, but not in their orientation, to the segregation accomplished by centrifugal force.

In wholly similar manner the shrinkage of the nucleus as a whole is relatively slight, whereas the segregation of chromatin from achromatin is the most distinctive action of hypertonic solutions on resting nuclei. The chromatin within

the nuclear vesicle is clumped or condensed into a single central mass, or into a dense reticulum of very coarse threads; the surrounding achromatin[1] is left free from granules of chromatin and yet it stains like oxychromatin and is identical with the material which I have elsewhere (1902) called "chromatic nuclear sap."

During mitosis this chromatic sap together with hyaloplasm from the cell body constitutes the archiplasm, which fills the area around the centrosomes, radiates along the astral fibers and forms the interfilar substance of the spindle as I have shown in the work just referred to (1902, p. 49). In hypertonic solutions this archiplasm is withdrawn from the astral radiations into the spindle and the area immediately surrounding it (figs. 189, 190). At the same time the entire spindle figure shrinks in size, the chromosomes are usually clumped together, and the spindle fibers may disappear. Eggs which have been returned from hypertonic solutions to normal sea water lose all appearance of shrinkage within a short time (Exps. 973, 977). Konopacki found that such eggs assume a normal appearance within five minutes after their return to normal sea water.

5. *Formation of Cytasters and Polyasters.*

(Figs. 183–190, 199, 203, 204, 206, 207, 213, 219, 220.)

All investigators who have made a cytological study of the effects of hypertonic solutions on eggs have emphasized the fact that the appearance of cytasters constitutes one of the most characteristic results.[2] Morgan (1899) in particular holds that the presence of cytasters (his astrospheres) rather than the suppression of cell division is the most distinctive effect of hypertonic solutions. Wilson (1901) believes that these cytasters may contain centrosomes, become the poles of spindles, and in every other way behave as veritable centers of mitotic division. Admittedly the evidence in favor of this view is not entirely conclusive, and Petrunkewitsch (1904) maintains that there is a fundamental distinction in these regards between "nuclear asters" and "cytasters," with which opinion I agree.

The exact method of the origin of cytasters has not been traced, except by Konopacki (1911), who finds that they arise along the astral radiations and from the material of which these radiations are composed. He finds that they appear most frequently before cleavage, more rarely in the 2-cell stage, and never in later stages. My own observations entirely confirm those of Konopacki in these respects. In 1902 I showed that cytasters never form when the germinal vesicle is intact, and that they form from archiplasm which is derived in part from escaped achromatin of the nucleus.

[1] The term "achromatin" as originally introduced by Flemming (1882) includes all materials of the nucleus other than chromatin. As thus used it is a generic term including oxychromatin, linin, nuclear sap, and possibly still other substances. Since these different substances are not distinguishable at every stage of the nuclear cycle it is convenient to have a generic term which will include any or all of them and it is for this reason that the term "achromatin" is used.

[2] Not infrequently cytasters appear in eggs under normal conditions, especially during the period between fertilization and the first-cleavage (cf. Exp. 996 (1), control on effects of electric current).

In the withdrawal of the archiplasm of the astral radiations into the spindle, certain portions may be left isolated along the rays, especially if these rays are very long, as is the case in the 1-cell and 2-cell stages. These isolated portions of archiplasm become the centers of new radiations, thus forming cytasters. These cytasters sometimes contain deeply staining granules, which have the the appearance of centrioles, and which may be derived from the axial filament of the radiation, but so far as my observations go, they never become the poles of spindles nor undergo division. On the other hand cytasters frequently fuse together, as Mead (1898) and Morgan (1899) have determined, whereas nuclear asters often divide, but rarely fuse. If very many cytasters are present in a cell the astral systems at the poles of the spindles are smaller than usual, because the archiplasm which largely composed these systems is distributed to many centers; this fact has been observed and commented upon by both Morgan and Wilson. Cytasters appear best developed during periods of mitosis and if a long resting period follows, the place of the cytaster is taken by a faintly staining vesicle of archiplasm or achromatin (figs. 186–188, 191, 192). The substance thus isolated forms a delicate membrane and gives rise to a small "nucleus without chromatin" (R. Hertwig). I have not determined positively that such an achromatic vesicle can give rise to another astral system at the next mitosis but such seems to be the case. Where cytasters occur during interkinesis it is invariably found that a large amount of archiplasm is distributed through the cell, as for example after the maturation divisions and before the first cleavage. It is well known that a great amount of achromatin escapes from the germinal vesicle at the time of the first maturation division, and this achromatin is widely distributed through the egg along the astral radiations. When the germ nuclei have grown large and have therefore absorbed a great deal of achromatin no cytasters are formed, especially in the vicinity of the nuclei, but when the nuclei are small and much achromatin is still scattered through the cell, cytasters may appear. *The cytasters are therefore, in my opinion, isolated portions of archiplasm, derived in large part from escaped achromatin, which take the aster form during mitosis and the vesicular form during resting periods* (figs. 183–193).

In addition to the presence of cytasters in eggs exposed to hypertonic sea-water, several nuclear asters may be present and since all asters within the same cell are in divisional activity at the same time, multipolar mitoses thus arise (figs. 203, 219, *et al*). These polyasters are found only in cells in which cleavage has been temporarily suppressed while centrosomal division proceeded, or in cells in which cleavage has been permanently suppressed, while the centrosomes have continued to divide after the eggs were returned to normal sea water; in the latter case their number is generally proportional to the length of time the eggs have been in normal sea water. These polyasters pass through periods of division, alternating with periods of rest, and there is reason to believe that they have arisen by regular division from an original single centrosome and aster in each cell; such division would give rise to, first amphiasters, then tetras-

ters, and finally polyasters in cases where the division of the cell body is inhibited, while that of the centrosome proceeds. *I have been unable to find any evidence whatever that centrosomes arise de novo in the eggs of Crepidula, or that cytasters become the centers of mitotic nuclear division.*

It is a striking fact, and one not easily harmonized with the hypothesis that centrosomes may arise *de novo*, or from the fragmentation of a single centrosome into many, that the number of nuclear centrosomes in eggs in which cleavage was suppressed by hypertonic sea water is approximately proportional to the length of time during which the eggs have remained in normal sea water following exposure to the hypertonic solutions. The maximum number of cytasters is found while eggs are still in the hypertonic solution (figs. 183, 189, 190) whereas in such eggs the nuclear asters are present in normal numbers. Only after such eggs have been returned to normal sea water for several hours during which time centrosomal division has been progressing while cell division remains suppressed do nuclear asters become numerous (figs. 203, 207, 219, *et seq.*). The only apparent exceptions to this rule are found in those cases in which the hypertonic solution (or other injurious condition) was not strong enough to stop centrosomal division, although strong enough to suppress cell division, and these exceptions are only apparent and really support the proposition that nuclear asters and centrosomes arise by the division of preexisting asters and centrosomes. Further evidence that the polyasters which occur in the eggs of *Crepidula* are not derived from cytasters may be found in the fact that polyasters may be found at any stage of the cleavage, whereas according to Konopacki and myself, cytasters are rarely found later than the 2-cell stage.

6. *Origin of the Cleavage Centrosomes.*

(Plate LV.)

All of the eggs represented in plate LV were placed in 1 per cent. NaCl in sea water for 4 hrs. and were then fixed at once. In all of these figures both polar bodies had been formed and the sperm had entered the egg before the experiment began. The effect of the hypertonic sea water has been to delay the movement of the sperm nucleus toward the egg nucleus and to stimulate the formation of an amphiaster in connection with the egg nucleus. The view was first expressed by Boveri (1892), and has been widely accepted by other investigators, that the egg centrosome is a decadent structure, which ultimately undergoes degeneration, while the two cleavage centrosomes arise in connection with the spermatozoon. In cases of normal or artificial parthenogenesis it is supposed that the cleavage centrosomes are derived from the egg centrosome, which in such cases becomes active, or they are new formations. My work on the normal processes of maturation and fertilization in *Crepidula* (Conklin, 1902) led me to the conclusion that *one of the cleavage centrosomes is formed in connection with each of the germ nuclei*, though it was impossible to say that they came from the

egg and sperm centrosomes, since the latter had disappeared as such, before the first appearance of the cleavage centrosomes.

In the eggs represented in figs. 159–163 various stages in the division of the egg centrosome and in the formation of the egg amphiaster are shown. That this centrosome and amphiaster actually belong to the egg and not to the sperm is beyond doubt, the sperm nucleus being so far removed from the egg nucleus and so isolated from it by intervening yolk that there is no possibility of confusing the two. In the figures mentioned the sperm centrosome and aster are not visible, if present. In fig. 164 two spindles are present in the egg, one of which is certainly the egg spindle and the other the sperm spindle; the same is true of fig. 168, in which the two spindles are entirely distinct. In all other figures on plate LV, viz., figs. 165–167, 169–170, the two spindles have not remained distinct, but their poles have interfered, thus giving rise to tetrasters.

I have discussed these figures elsewhere (Conklin, 1904) and need not comment on them here further than to call attention to the fact that the origin of amphiasters in connection with each of the germ nuclei, when the latter are kept apart, indicates that the egg centrosome does in this case persist, and that it may be stimulated to divide and form an amphiaster by methods which have elsewhere been employed to produce artificial parthenogenesis. In all probability this is just what occurs in every case of normal or artificial parthenogenesis; the cleavage centrosomes being derived from the egg centrosome, and not being formed *de novo*.

Kostanecki (1906, pp. 386–394) has commented at some length on my conclusions as to the origin of the cleavage centrosomes in *Crepidula* under normal and artificial conditions. So far as the origin of these centrosomes under normal conditions is concerned I again admit, as I have done in previous papers (1901, 1902, 1904), that the evidence is not conclusive that they come, one from the egg centrosome and the other from the sperm centrosome, since both of the centrosomes have disappeared as such before the cleavage centrosomes appear. On the other hand the persistence of the egg and sperm spheres until the union of the germ nuclei, the fusion of the spheres and the appearance of a cleavage centrosome in connection with each of the germ nuclei, the absence at all stages of the normal process of an amphiaster in connection with either the egg or the sperm nucleus—these incontrovertible facts do not afford evidence for the view that the cleavage centrosomes always come from the sperm centrosome. I freely admit that in many instances such an origin may be clearly traced. In certain ascidians which I have studied (Conklin, 1905) there are no centrosomes in either the first or second maturation divisions, and none at any stage in connection with the egg nucleus; while the origin and division of the sperm centrosome and its transformation into the sperm amphiaster and into the first cleavage spindle can be determined with the greatest certainty. There is here a great difference between *Ciona* or *Cynthia* and *Crepidula* or any other gasteropod.

These differences may be summarized in the following tabular statement:

CREPIDULA.	CIONA.
Egg with abundant yolk.	Egg with little yolk.
Large centrosomes and asters in both maturation spindles.	No centrosomes or asters in either maturation spindle.
Egg centrosome remains evident for some time and then disappears in egg sphere.	No egg centrosome at any stage.
Egg aster gives rise to large sphere which persists till germ nuclei conjugate.	No egg aster or sphere at any stage.
Sperm nucleus moves very slowly toward egg nucleus; first cleavage is about 6 hrs. after fertilization.	Sperm nucleus and egg nucleus move rapidly toward posterior pole; first cleavage is about 40 min. after fertilization.
Sperm nucleus, centrosome and aster lie for 3 or 4 hrs. in compact yolk and remain small.	Sperm nucleus, centrosome and aster lie in cytoplasm from the first and grow rapidly.
Sperm centrosome does not divide but disappears in sperm sphere which persists till germ nuclei conjugate.	Sperm centrosome divides giving rise to sperm amphiaster.
Egg and sperm spheres fuse and disintegrate when germ nuclei conjugate, and one cleavage centrosome appears close to each nucleus, and the cleavage spindle forms between them.	Sperm amphiaster becomes the central spindle of the first cleavage.

When to these differences in the normal phenomena of fertilization is added the fact that hypertonic sea water may cause a perfect spindle to form in connection with each of the germ nuclei in *Crepidula* but that no means has yet been found, though many have been tried, to cause a spindle to form in connection with the egg nucleus of ascidians, the extent of the differences between the eggs of these two types will be appreciated.

The view that this difference ceases when we come to the actual origin of the cleavage centrosomes is based not upon actual evidence but upon the conviction that a single, uniform origin of these centrosomes must be expected,—that in spite of all other differences there must be uniformity in this regard. And yet nothing is more certain than that the cleavage centrosomes do not have a uniform origin in all cases, that while, in many instances they arise in connection with the sperm nucleus, in all cases of normal or artificial parthenogenesis they cannot have such an origin. There is not therefore a single, uniform origin of these centrosomes in all animals, and consequently there is no antecedent probability that the differences observable between *Crepidula* and *Ciona*, for example, with respect to other phenomena of maturation and fertilization do not also extend to the origin of the cleavage centrosomes. If it were certain that the cleavage centrosomes invariably come from the sperm centrosome in fertilized eggs, and invariably from some other source in parthenogenetic eggs,

there would be ground for establishing a fundamental distinction between these two types of eggs; but *the fact that any one of many slight changes in the environment may cause a non-parthenogenetic egg to become parthenogenetic indicates that no such distinction can be of a very fundamental nature, and it also indicates that there is no inherent improbability in the view that cleavage centrosomes may in some cases arise from the egg centrosome as well as from the sperm centrosome.*

Kostanecki believes that my views are based upon a too narrow consideration of the case of *Crepidula*. I, on the other hand, believe that the view that the cleavage centrosomes always come from the sperm centrosome is based upon a too narrow view of the conditions in certain fertilized eggs, with a corresponding neglect of the conditions in normally and artificially parthenogenetic eggs.[1] I cannot better sum up my present views on this subject than by quoting the conclusions reached in a former paper (1902, p. 30), to which I still adhere: "When one looks at the problem of fertilization from a general point of view, when one considers the universality of sexual reproduction, when one reflects upon the multitudes of exquisite adaptations which exist for securing the union of egg and sperm, he will be loath to believe that the essential feature in fertilization is the addition of a centrosome to the egg cell, or the supplying of a stimulus to its development, which is not needed in all cases and which can as well be supplied by changes in density, salinity, temperature, etc., as by the entrance of a spermatozoon."

7. *Irregularities in the Movements of Chromosomes.*

In the separation of daughter chromosomes great irregularities appear; "lagging" chromosomes are almost always present and in many cases the chromosomes are scattered along the whole length of the spindle (figs. 211–222). As a result of these irregularities of movement on the part of the chromosomes they are not distributed equally to the two poles of the spindle and they do not come together at the poles to form a single nuclear vesicle, but they become associated in varying numbers to form vesicles, or karyomeres, of different sizes, depending upon the number of chromosomes which enter into them, while if scattered along the whole length of the spindle, the chromosomes may form a continuous chromatic connection between daughter nuclei, thus giving rise to conditions which are falsely suggestive of amitosis. The karyomeres may be few

[1] Wilson (1897) demonstrated that in echinid eggs the entire middle piece of the spermatozoon was not involved in the formation of the sperm centrosome. Meves (1911) has shown that no portion of the middle piece is necessary for the formation of the sperm centrosome. F. R. Lillie (1912) in a recent and most important paper has shown that in *Nereis* both middle piece and tail of the spermatozoon remain outside the egg and that the sperm centrosome arises from the base of the sperm head. Furthermore portions of the elongated sperm nucleus may be stripped off from the egg along with the jelly membrane, by centrifugal force, and in such cases the sperm centrosome always arises from the basal end of that portion of the nucleus which enters the egg, and is proportional in size to the quantity of nuclear material which thus enters. He concludes "that the centrosome and aster owe their existence to an interaction between nucleus and cytoplasm and not to any third element." The view that the cleavage centrosome can come only from the centrosome of the spermatozoon is evidently losing ground.

or many in number, and they may be entirely distinct or may be partially united, thus giving rise to nuclear forms which might be interpreted as nuclear constriction or budding (figs. 175, 177, 194–196, 198, 200–202, 205–208). Indeed they are so interpreted by Konopacki, but in *Crepidula* a careful study of the karyomeres with regard to their stages in the nuclear cycle shows that the unions are more complete in the later than in the earlier stages, thus proving that they are fusing rather than separating. However, where the karyomeres are quite distinct they may remain separate in all the cells through several cell generations (figs. 205–208); evidently the union of the karyomeres into a single vesicle can take place only when they are in intimate contact.

In all my preparations the nuclear vesicles are much more numerous than the nuclear asters. If both nuclei and asters multiplied by constriction or fragmentation this condition would be difficult of explanation, but if the nuclear asters and centrosomes arise by bipartition, while the karyomeres come from scattered chromosomes, the explanation of this condition is obvious. The centrosomes are unit structures, the nuclei are compound, being composed of many chromosomes or chromosomal vesicles; while each centrosome becomes the center of an aster, each chromosome does not usually form a separate nuclear vesicle, though it is capable of doing so, but unites with other chromosomes to form one or many nuclear vesicles.

Considering the fact that these irregularities in the movements of chromosomes are among the most common forms of abnormal cell division whatever the disturbing factor may be, the question arises whether many of the cases of amitosis in normal developmental processes, which have been recently described, may not be really cases of the formation of separate karyomeres, and their subsequent fusion, such as occurs in these experiments. I refrain from commenting here on this subject further than to suggest that many of the figures given by recent writers on this subject bear a striking resemblance to these karyomeres of *Crepidula*. In the latter case, however, the actual lineage of these karyomeres may be determined with great certainty and it can be affirmed that they arise from irregularities in the separation of chromosomes in mitotic division.

The size of these karyomeres is, within the same cell, proportional to the number of chromosomes which enter into them, as Boveri (1905) found to be the case in echinoderm eggs. However in cells which differ in their quantity of cytoplasm, nuclei and karyomeres may differ in size, though they contain the same number of chromosomes, since the ultimate size of a nucleus depends not merely upon the number of chromosomes which it contains but also upon the quantity of cytoplasm in which it lies (Conklin, 1912).

8. *Segregation of Chromatin and Achromatin.*

Attention has already been called to the fact that isolated portions of achromatin may assume the form of cytasters during periods of mitosis and of vesicles with a definite membrane during periods of rest. The former condition

is illustrated in figs. 183, 185, 189, 190; the latter in figs. 184, 186, 188, 191. When eggs are left for a long time in salt solutions, the chromosomes of daughter nuclei are unable to absorb achromatin and to become vesicular but remain small, densely chromatic masses, and in such cases the achromatin forms vesicles which may lie close to the chromatin (figs. 184–188) or may surround the chromatin while remaining distinct from it (figs. 178–183). Indeed the entire achromatic portion of the mitotic figure, with the exception of the centrosomes and spheres, which always remain distinct, may be inclosed in the achromatic vesicle (figs. 178–182). Apparently the achromatic vesicle does not form until the telophase of division, and even then it may form in the place of one spindle and not of another (fig. 180), or in one of two daughter cells and not in the other (fig. 181). This achromatic vesicle has a very thin membrane and the whole vesicle is elongated in the direction of the spindle axis. Since this achromatic vesicle conforms to the outlines of the spindle in telophase, it is conical in shape, its base being turned toward the centrosome and its apex toward the *Zwischenkörper*. The appearance of two such conical vesicles in daughter cells with their apices turned toward each other, is strongly suggestive of the constriction and amitotic division of the achromatin. It resembles still more those forms of nuclear division in which the chromatin divides mitotically, but in which the nuclear membrane persists throughout the process, and it and the achromatin divide by constriction. However in this case there can be no doubt that the nuclear membrane actually disappears in mitosis while the membrane which forms around the achromatin is a new structure called forth by the action of the salt solutions. Konopacki has observed and figured in echinoderm eggs subjected to hypertonic solutions conditions similar to those just described for *Crepidula*. He finds, as I do also, that this membrane is not of the usual type, but is much thinner, nevertheless he seems to regard these forms as due to an elongation and constriction of the nuclear vesicle, in which, presumably, the membrane persists throughout division. Such is plainly not the case in my experiments, where this achromatic vesicle may be present in one daughter cell and not in the other, as in fig. 181. Kostanecki (1904) has described a form of "intranuclear karyokinesis" in eggs of *Mactra* subjected to hypertonic solutions in which a spireme, chromosomes, and a bipolar spindle form within the nuclear vesicle; the chromosomes separate and move to the two poles and the vesicle and central spindle then disappear while the chromosomes form daughter nuclei. During this whole process faint radiations may be present in the plasma, but there are no centrosomes or astral systems. I have not observed this form of mitosis in *Crepidula*.

These results throw light on the constitution of the nuclear membrane. By various writers this membrane has been held to be composed of an outer plasmatic or achromatic layer and an inner nuclear or chromatic one. My own observations (1902) led me to adopt the view of Van Beneden (1887) that this membrane was formed from the peripheral walls of the chromosomal vesicles, which

fuse to form the nuclear vesicle. Its outer achromatic layer was supposed to be derived from the sheath of linin covering the chromosomes themselves. In the light of the observations here recorded it is evident that *an achromatic membrane may be formed wholly independently of the chromosomes. This membrane is thinner than the usual nuclear membrane and it lacks a chromatic layer. It is probably a precipitation membrane.*

Evidently the growth of the nuclear vesicle in hypertonic solutions and its ability to absorb achromatin is dependent to a certain extent upon the stage of development of the nucleus, and more particularly of the chromatic membrane. In figs. 171 and 172 the egg nucleus has remained small and its vesicle contains only chromosomes and a very clear fluid, in spite of the fact that this nucleus lies in the cytoplasmic area, the nuclear membrane is also thin and achromatic; the sperm nucleus, on the other hand, has grown to a great size and contains most of the achromatin (chromatic sap) which was previously scattered through the cell. If the egg nucleus has passed a certain stage in its development from the chromosomes which were left in the egg after maturation, it also grows, as the sperm nucleus does, and if the resting period is prolonged both germ nuclei may become very large (fig. 173). If any of the achromatin is scattered through the egg as cytasters or vesicles (fig. 174) the germ nuclei are correspondingly smaller. These results indicate that the substance absorbed by the nucleus from the cell is a specific substance and not merely the general material of the cell body.

In a previous paper (1912) I have shown that young nuclei grow by the absorption of material from the middle zone of centrifuged eggs, and not from the lighter or heavier zones. The growth and ultimate size of nuclei was found to be proportional to the abundance of the material of this middle zone, and to the length of time during which it was being absorbed by the nucleus. From the present work it is apparent that *the substance which contributes most largely to the growth of the nuclear vesicle is achromatin which escaped from the nuclear vesicle at some previous mitosis. This achromatin, or chromatic sap, forms the interfilar substance of the spindle and asters and radiates through the cell along the astral fibers; it gives rise to cytasters and achromatic vesicles; it contributes to the growth of the daughter nuclei; it is probable that chromatin grows at its expense and that it in turn receives certain substances from the chromatin; and finally it seems likely that it is this achromatin which establishes connections between the chromatin and the cell body, through which connections the influence of the chromosomes on the differentiations of the cell body are exerted.*

9. *Abnormal Mitosis and Amitosis.*

There are many abnormal mitoses in these experiments which are superficially like amitoses. Among these may be recognized the following classes: (1) Those which are due to irregular separation of daughter chromosomes which are scattered along the length of the spindle; in these forms a chromatic connection is left between daughter nuclei which is at first glance strongly suggestive

of amitosis but a careful study of these nuclei which are connected by a chromatin thread shows that in *Crepidula* at least, they are invariably formed in the manner stated (figs. 141, 143, 144, 152–154, 215, 222). It is highly probable that the number of chromosomes which go into two such daughter nuclei is not the same. Such eggs do not give rise to normal embryos or larvae though subsequent cleavages may go on in a manner which is approximately typical. (2) Apparent amitosis due to the constriction of the achromatin and of the achromatic vesicle following the mitotic division of the chromatin. It is evident that this is merely a variation of the condition found in certain protozoa in which the nuclear membrane does not disappear, and an intranuclear spindle is formed. In *Crepidula*, however, the membrane does disappear, but if the daughter chromosomes are prevented from absorbing achromatin, an achromatic membrane may form around the achromatin of the spindle area, and in the later stages of mitosis such figures may look like amitotically dividing nuclei (figs. 178–182). (3) Apparent amitosis really due to the fusion of karyomeres. Many such cases are shown in my figures. Karyomeres are formed whenever daughter chromosomes are slightly separated into groups; this is especially the case when polyasters are present. These karyomeres may be very numerous, but those which are in contact fuse together during the resting period, so that they become progressively larger and less numerous in later stages of the division cycle (figs. 121, 124, 136, 145–150, 175, 177, 192–223).

Much interest has been shown of late in the question whether amitosis occurs in germinal or embryonic cells, since if it does it thereby weakens if it does not destroy the belief in the chromosomes as the sole "bearers of heredity." I hold no brief for this doctrine and have repeatedly urged (1893, 1899, 1905, 1908, etc.) its too narrow outlook on the activities of the cell as a whole. It seems to me incredible that this most general of all cell functions, which includes differentiation, metabolism and reproduction should be the property of only a single cell constituent,—the chromosomes. I have therefore approached this problem without any preconceived bias as to the theoretical necessity of believing in mitosis in all divisions of generative or embryonic cells, and have not been consciously warped by either the *odium mitoticum* or the *odium amitoticum*.

An excellent review of this whole subject is given in Wilson's book, *The Cell* (1900), and in Godlewski's (1909) notable memoir on the inheritance problem, and I shall confine my attention to a consideration of some of the more important recent contributions on amitosis.

After the discoveries which showed that mitosis was the usual form of nuclear division, most of the workers who studied amitosis found it limited to cells already fully differentiated and usually decadent. In recent years a new interest has been given to the problem by the work of Child (1907[1], 1907[2], 1910, etc.), Hargitt (1900, 1904), Patterson (1908), Glaser (1908), Gurwitsch (1905), Gerassimoff (1892), Nathansohn (1900), Foot and Strobell (1911), *et al.*, all of whom maintain that amitosis may occur as a normal process in germinal and embryonic cells.

On the other hand this view is contested by Boveri (1907) and Strasburger (1908) on general grounds and is not confirmed by the observations of Richards (1909, 1911), nor by the experiments of Häcker (1900) and Schiller (1909) on *Cyclops* eggs subjected to ether, nor by the experiments of Němec (1903), who repeated the work of Wasielewski (1902, 1903) on root tips of *Vicia* subjected to chloral hydrate, and reached the conclusion that the supposed amitoses have arisen through the transformation of normal mitotic figures.

On the other hand R. Hertwig (1898), Herbst (1909), Godlewski (1909), Konopacki (1911), Lang (1901), Calkins (1901) hold that there is no principal distinction between mitosis and amitosis and that they may both occur without interference with normal processes of reproduction and differentiation.

So far as concerns many of the observations and experiments named it must be admitted that they are not critically conclusive; either it is not shown beyond question that the divisions are genuine amitoses, or it has not been proved that the cells are normally differentiating embryonic cells. In particular most if not all of the figures given by Child, Hargitt, Patterson, Glaser and Gurwitsch may be duplicated by figures in which it is known that division is by mitosis. The wholly or partially distinct nuclear vesicles may be fusing rather than separating, and such is undoubtedly the case in my experiments. Godlewski recognizes the difficulty of distinguishing the fusions of karyomeres from direct nuclear divisions, but in my experiments this distinction can be made with certainty, not only because every stage in the formation and fusion of karyomeres may be seen in the division of a particular cell, but also because the relative stages of karyomeres in the division cycle can be distinguished by the character of the chromatin, and the fusions are always more complete in the later than in the earlier stages.

A further matter to which I believe attention has not hitherto been called is that the scattering of chromosomes along the length of the spindle leads to the formation of chromatic connections between daughter nuclei in the resting stage. Such chromatic connections have hitherto been accepted as undoubted proof of amitosis, and Godlewski in his review, after dismissing many other more or less doubtful cases, bases his conclusion that amitosis may occur in normally differentiating tissue upon the undoubted cases given in the works of Gurwitsch and Nathansohn. I am unable to speak from personal experience of the results obtained by the last named investigator in his experiments on *Spirogyra*, but the figure given by Gurwitsch of a mitotic division following an amitotic one in a blastomere of a centrifuged Triton egg, cannot go unquestioned. The chromatic connection between the two nuclei shown, is no evidence of amitosis, but rather of the scattering of chromosomes along the spindle, at the previous division of these cells. I have repeatedly observed such scattered chromosomes and the resulting chromatic connections between daughter nuclei, in practically all of my experiments, though they are figured chiefly in eggs subjected to diluted sea water; they also occur in centrifuged eggs, as I shall show in a later paper.

Of the occurrence of amitosis in protozoa I shall not here treat; the conditions in these forms are peculiar, and the form of nuclear division may also be peculiar, but it seems to me that there is as yet no satisfactory evidence that amitosis ever occurs in normally differentiating cells of the metazoa. Godlewski concludes (p. 120): "Dass aus der bisherigen Literatur sich kein einzige Aufgabe anführen lässt, durch welche ganz positiv bewiesen wurde, dass die Amitose der Karyokinese nicht gleichwertig sein konnte." On the other hand, I think it may be affirmed with equal emphasis that *there are numerous evidences against the view that amitosis can take the place of mitosis in normally developing cells of the metazoa, and not a single entirely positive one in favor of that view.*

XI. Conclusions and Summary.

A. Observations and Experiments.

1. In the eggs of *Crepidula plana* abnormal cleavages and mitoses are relatively rare in the conditions found in nature; those which occur are due, probably, to pressure, diluted sea water, or increased temperature. (Figs. 1–29; pp. 505–507.)

2. The cleavage of isolated blastomeres is strictly partial; the only modifications as compared with entire eggs being due to the rounding of the isolated cells. All the early cleavages are differential (morphogenetic); non-differential cleavages appear only after the formation of ectomeres, mesomeres and entomeres, and in certain subdivisions of these cells. So far as the cleavage stages are concerned the prospective significance and the prospective potency of early blastomeres are identical. (Figs. 30–44; pp. 508–510.)

3. In eggs under pressure lobes may be formed, usually opposite the poles of the spindles; spindle axes and cleavage planes may be turned out of their normal positions, so that the blastomeres formed lie in one plane and bear totally atypical relations to one another and to the axes of the unsegmented egg; if the pressure is in the direction of the spindle axis, but is not sufficient to turn the spindle out of that axis, it may lead to suppression of cell division. In all cases the prospective significance and the prospective potency of such blastomeres, during the cleavage stages at least, is determined by the relations of the cleavage planes to the axes of the unsegmented egg. All cells formed by meridional cleavages give rise to three separate ectomeres at the animal pole, and to one entomere at the vegetal pole; all cells formed by equatorial or latitudinal cleavages are ectomeres at the animal pole, entomeres at the vegetal pole; mesomeres arise only from cells lying between these poles on the posterior side of the egg. There is, presumably, a stratification of the hyaloplasm, or "ground substance," of the unsegmented egg, wholly apart from the yolk or other inclusions, which determines the morphogenetic trend of each blastomere. (Figs. 45–67, 76, 77; pp. 510–518.)

4. When eggs are subjected to a weak electric current, spindles, nuclei and cytoplasm may be displaced as if by pressure and subsequently formed blasto-

meres may be abnormal in position. With a stronger current (or more perfect penetration) chromatin and chromosomes may be clumped into masses or even completely dissolved, while the spindles and asters may be preserved in some cases or dissolved in others. With a stronger current (or more perfect penetration) cytoplasm and yolk may be stratified and nuclei and spindles displaced by convection currents. There is no indication that the poles of spindles bear charges differing in sign from the chromosomes, or that spindle fibers or astral rays represent lines of force in an electric field, or that the movements of chromosomes into or out of the equatorial plate are caused by electric charges carried by the chromosomes and centrosomes. (Figs. 68–93; pp. 518–524.)

5. Increase of temperature from 10° to 16° above that of normal sea water, if only for ¼ hour, leads to profound modifications of cell division. The most general effects are: (1) Reduction of surface tension, with consequent irregularities in the contour of eggs and changes in the type of cleavage. (2) Withdrawal of astral rays and segregation of archiplasm in the spindle area and along the walls between cells. (3) Great changes in the orientation and structure of mitotic figures; loss of spindle fibers and centrosomes; scattering of chromosomes and formation of numerous karyomeres. (Figs. 94–99; pp. 524–525.)

In eggs kept near the freezing point all divisional phenomena are soon stopped; after 14–16 hrs. on ice the centrospheres, during resting stages, become bounded by a definite membrane and look like faintly-staining nuclei; after 40 hrs. on ice centrospheres break up into coarse, chromatic granules, which may be homologous with mitochondria. (Figs. 100–105; pp. 525–526.)

6. In 1 per cent. and 2 per cent. solutions of ether in sea water cell division proceeds with few modifications; in 3 per cent. solutions all karyokinetic and cytokinetic movements cease and cell division is suppressed, archiplasm is withdrawn into the central portion of the aster and into division walls between cells, chromatin is clumped in resting nuclei, chromosomes are scattered along the spindles, and spindle fibers are indistinct or absent. (Pp. 526–527.)

7. In water in which the oxygen tension is reduced by boiling, or by running a current of hydrogen through it, cell division is greatly retarded or completely stopped, but cleavages are normal in type as far as they go; resting nuclei and nucleoli become larger than usual during the long interkineses, and the chromatin is clumped into a nucleolus-like mass; centrospheres lose their definite outlines and consist of coarse, widely-scattered granules; spindle fibers, chromosomes and centrosomes remain distinct, but astral radiations disappear, the archiplasm being drawn into the central figure of the amphiaster and into the division walls between cells. (Figs. 106–118; pp. 527–529).

8. Addition of CO_2 to sea water causes local reductions in the surface tension of both cells and nuclei, whereby their surfaces become lobulated; also the positions and directions of mitotic figures and of the resulting cell divisions are altered. (Figs. 119–131; pp. 530–532.)

9. Hypotonic sea water may induce polyspermy; isolation of blastomeres;

suppression of cleavage in the yolk, with subsequent formation of polyasters and meroblastic cleavage; scattering of chromosomes, with consequent formation of karyomeres, chromatic connections between daughter nuclei, and amitosis-like figures. (Figs. 132–158; pp. 532–536.)

10. In sea water rendered hypertonic by the addition of KCl, NaCl, or $MgCl_2$, yolk cleavage is suppressed in weaker solutions, protoplasmic cleavage in stronger solutions, nuclear and centrosomal divisions in still stronger solutions; archiplasm, chromatin and mitotic figures shrink, and cytasters are formed from isolated portions of archiplasm of the astral radiations; multiple nuclei and multipolar spindles are due to the suppression of cell division while nuclear and centrosomal divisions proceed; irregular movements of chromosomes lead to the formation of isolated chromosomal vesicles or karyomeres; achromatin may separate from chromatin and form achromatic vesicles with achromatic membranes. (Figs. 159–223; pp. 536–550.)

B. Cleavage and Differentiation.

11. Early stages in development are more easily influenced by environmental changes than are later ones; and stages during kinesis are more susceptible to modification than stages during interkinesis. Almost all persistent alterations of structure occur during cell division, few of those which occur during the resting period are permanent. That this is due primarily to interference with the divisional apparatus rather than to increased permeability of the plasma membrane during division is indicated by the facts (1) that this is true of eggs subjected to pressure and to the electric current as well as to the various solutions used; (2) that weak solutions produce more changes of a permanent character when acting during kinesis, than do much stronger solutions acting during interkinesis; (3) that practically all persistent modifications of structure are those which affect the division of nucleus, centrosome or cell body, whereas great modifications of structure during the resting period quickly disappear when the eggs are returned to normal conditions. The cause of this is evidently to be found in the fact that when chromosomes, centrosomes or differentiated portions of the cell body are once distributed abnormally to the two daughter cells there is no possibility of bringing about a normal redistribution of these structures, owing to the intervention of the division wall. (Pp. 537, 538.)

12. The study of the development of eggs under pressure, and of isolated blastomeres, shows that there is a polar-bilateral organization of the egg, that the early cleavages are typically differential, and that the prospective significance and the prospective potency of the early blastomeres are identical. On the other hand the nuclear divisions are non-differential and the early nuclei totipotent. (Pp. 515–518.)

13. The causes of differential cleavage are to be found in the relations of the spindle axes and the cleavage planes to the organization (differentiation and localization) of the cell substance. The position of the mitotic figure in a cell is

due to several factors: (1) The separation of daughter centrosomes at right angles to the cell axis (the axis passing through centrosome, nucleus and mid-body), and in the plane which separates the gonomeres. (2) Telokinetic movements at the close of each mitosis by which the cell axis undergoes regular changes with respect to the axis of the egg as a whole, the poles of the cell axis always moving toward the animal pole and toward the point where the previous cell constriction began. (3) Local reductions of tension of the cell membrane in certain axes, or increase of tension in other axes, by which an axis of least resistance is established in the cell. (4) Mitotic movements of the cell contents, which begin with the dissolution of the nuclear membrane in the prophase, and which cause the spindle and the surrounding plasma to move into certain definite axes and positions in the cell. Of all of these factors the last named is, during the early cleavages at least, the most important and the most difficult of explanation.

14. Cleavage furrows may be suppressed, without stopping subsequent nuclear and centrosomal divisions, by shaking, pressure, increased temperature, carbonic acid, diluted sea water and concentrated sea water. The first and second cleavages may be suppressed without stopping subsequent cleavages, and in this way a holoblastic type of cleavage may be transformed into a meroblastic type.

(1) When the second cleavage furrow is suppressed subsequent cleavages may go forward in typical manner, provided the two mitotic figures in each blastomere (*AB*, *CD*) remain so far apart that they do not interfere; in this way three quartets of typical ectomeres (1*a*–1*d*, 2*a*–2*d*, 3*a*–3*d*) may be formed and at the fourth cleavage of the blastomere *CD*, two mesentoblasts (4*c*, 4*d*) may form simultaneously, at the 24-cell stage, although in typical development 4*c* is not a mesomere but an entomere, and does not form until the 52-cell stage. Within the same cell two mitoses are always simultaneous, and the resulting daughter cells are similar. The importance of division walls and of the isolation of morphogenetically and chemically different substances in differentiation is thus clearly indicated. (Figs. 123, 129, 157, 158; pp. 531, 532, 534, 538–540.)

(2) If the two mitotic figures in each of the macromeres (*AB*, *CD*) interfere, thus forming triasters or tetrasters, subsequent cleavages are not typical, but each macromere usually forms a single ectomere at each cleavage (1*ab*–1*cd*, 2*ab*–2*cd*, 3*ab*–3*cd*), the ectomeres thus being formed in sets of two instead of in sets of four, as in typical cleavage; of course the nuclei and centrosomes in such ectomeres are usually abnormal; however the fact that, in such cases, three sets of ectomeres may be formed in the typical directions, although the mitotic figures are very abnormal, indicates that typical, differential cleavage is a function of the cytoplasm rather than of the nucleus, and that the positions of the spindles and the locations of the cleavage planes are principally determined by the cytoplasm. (Figs. 123, 128, 137, 138, 211, 212, 213; pp. 531, 535.)

(3) If both first and second cleavages are suppressed multipolar spindles are

present in subsequent mitoses, since the four centrosomes which are typically present in such an egg are sure to interfere; subsequent cleavages lead to the formation of ectomeres which may be formed in sets of one, though the number of sets and the directions of division are difficult to identify; there seems no doubt however of the tendency on the part of the cytoplasm to cut off characteristic ectomeres at the animal pole, even though the nuclei and their divisions may be very atypical. (Figs. 6–8, 120, 121, 134, 135, 145, 148, 197–208; p. 539.)

(4) When either the first or second cleavage furrow is suppressed but the nuclear division goes on, subsequent cleavages may form more or less normally, but the suppressed cleavage is never repeated; if the egg is prevented from completing one of these divisions in its proper sequence it never returns to that division but goes on to the next in order. On the other hand if the third cleavage is turned out of its typical position, so that it becomes meridional instead of latitudinal, the next cleavage in order is morphogenetically the third cleavage, and is typical barring the number of macromeres and micromeres, which is double the typical number; the imposed meridional cleavage is a new one, intercalated between the typical second and third cleavages.

C. Mitosis and Amitosis.

16. In eggs subjected to an electric current there is no evidence that the centrosomes and chromosomes carry electric charges which differ in sign; nor that the mitotic spindle and the astral rays are chains of granules along lines of force in an electric field; nor that the movements of chromosomes into or out of the equatorial plate are due to the attractions or repulsions of electrically charged bodies. On the contrary, when mitotic figures are displaced by convection currents they move as a whole; the spindle fibers are actual threads of more consistent plasma than the surrounding parts, and may undergo bending and stretching without interrupting their continuity; the typical movements of chromosomes into and out of the equatorial plate cannot be explained consistently on the hypothesis that these movements are due to electrical attractions or repulsions between centrosomes and chromosomes. (Pp. 520–524.)

17. As the result of former observations (1902) and present experiments I conclude that the mitotic figure is, in the main, the expression of complicated diffusion phenomena between nucleus, centrosome and cell body; at the beginning of mitosis the "chromatic nuclear sap" (achromatin, archiplasm) escapes from the nuclear vesicle, when the membrane dissolves; it fills the areas around the centrosomes and radiates from these areas and from the entire amphiaster into the cell body; the spindle fibers, although consistent threads, are not preformed structures, but they grow, when first in contact with the chromosomes, in a manner suggestive of the formation of fibrin threads in clotting blood; it is theoretically possible to explain the division of chromosomes and their movement into and out of the equatorial plate by such formation and growth of polar fibers and of interchromosomal (interzonal) fibers; in later stages of mitosis the

spindle fibers are dissolved and taken into the daughter nuclei along with other achromatin (interfilar substance, archiplasm). During later stages of mitosis much of the archiplasm (achromatin) flows from the astral radiations into the central area of the aster and spindle, the daughter chromosomes absorb achromatin, thus becoming vesicular, and these chromosomal vesicles then fuse into several karyomeres and finally into a single nuclear vesicle the wall of which is composed of an outer achromatic membrane and an inner chromatic one, while the chromatin within the membrane takes the form, at different stages, of vesicular walls, reticulum, or granules. (Pp. 520, 542, 543.)

18. The diffusion phenomena between nucleus and cell body may be interrupted or modified by changes in the environment (increased temperature, decreased oxygen tension, ether, diluted sea water, hypertonic sea water) and the material of the astral radiations may be withdrawn into the central area of the amphiaster or into the ectoplasmic layer, or isolated portions of it may be scattered through the cell body. These altered conditions not only prevent diffusion between different substances but they bring about a shrinkage or segregation of these substances, (figs. 94, 96–99, 116, 117, 183, 189, 190). During 1-cell and 2-cell stages when astral radiations are extensive and much achromatin from the germinal vesicle is distributed through the cell, isolated portions of this achromatin form cytasters (figs. 183, 189, 190, 201); these may contain central granules but not true centrosomes; they fuse together but rarely if ever divide, and they never form the poles of nuclear spindles; the size of amphiasters and of nuclei is inversely proportional to the number and size of these cytasters (figs. 171–176, 183–190, etc.), thus indicating that the substance of the cytasters is achromatin withdrawn from the amphiasters and nuclei; if by the continued action of hypertonic solutions cytasters are prevented from fusing with amphiasters and nuclei they form during interkinesis delicate achromatic membranes, thus becoming achromatic vesicles, or "nuclei without chromatin," which may be widely scattered through the cell (figs. 174, 184–191). If the daughter chromosomes are prevented by hypertonic solutions from absorbing achromatin they remain a densely chromatic mass which does not become reticular or granular, and if resting nuclei with their chromatin in the form of a loose reticulum are treated with hypertonic solutions, the chromatic net at once contracts into a dense central mass, suggestive of normal synezesis, which is surrounded by achromatin and achromatic membrane (figs. 178–192). When the typical swelling of the chromosomes, by the absorption of achromatin, is prevented, a delicate achromatic membrane may form around the achromatin of the spindle area, within which the daughter chromosomes form a dense chromatic mass (figs. 178–182); or the achromatic vesicle may form on one side, or some distance from the chromatic mass (figs. 184–188).

19. Cytasters do not, in *Crepidula*, contain true centrosomes nor take part in nuclear division; on the other hand nuclear centrosomes and asters arise, during cleavage at least, by the division of preexisting centrosomes. If cell

division is suppressed while centrosomal division proceeds many centrosomes and asters (polyasters) appear in the cell, but there is no evidence that these arise *de novo* or from cytasters. If the union of germ nuclei, after fertilization, is delayed, the egg centrosome may divide, giving rise to a spindle, and at the same time a spindle may form in connection with the sperm nucleus; if these spindles are far apart they remain independent, if near together they interfere, thus producing tetrasters or triasters (figs. 159–170). The cleavage centrosomes do not invariably arise from the sperm centrosome. (Pp. 542–547.)

20. Many different environmental changes (shaking, pressure, increased temperature, ether, carbonic acid, diluted and concentrated sea water) may cause abnormalities in the separation of daughter chromosomes, and in their fusion to form daughter nuclei. Chromosomes may lag in the equator or be scattered along the length of the spindle, in which case there is left a chromatic connection between daughter cells (figs. 140–144, 152–154); slight separations between chromosomes at the poles of the spindle lead to the formation of separate vesicles or karyomeres (figs. 120, 121, 124, 136, 145–150, 174, 175, 192–223). Such conditions superficially resemble amitoses, but are true mitoses; there is no entirely conclusive evidence that amitosis ever occurs in the origin of the sex cells of metazoa or in the divisions which accompany embryonic differentiation. (Pp. 547–553.)

XII. Catalogue of Experiments on Nuclear and Cell Division in Crepidula.

(Every number represents a separate microscopic slide, and in most instances a separate experiment. The average number of eggs on each slide is not far from one thousand. All preparations were fixed, stained and mounted in balsam, as described on p. 504. All slides are preserved as permanent preparations and have been repeatedly consulted.)

I. Abnormalities Found in Nature.

In addition to occasional abnormalities found among eggs which were prevailingly normal, the following layings were prevailingly abnormal.

Number.	*Stage.*	*Abnormal Conditions.*	*Results.*
942	1-cell to young veliger.	Water warmer and less dense than normal.	Ectodermal cap not overgrowing yolk; exogastrulæ and exolarvæ, figs. 27–29.
943	1-cell to gastrula.	Unknown.	Giant eggs caused by fusion of two or more eggs.
944	1-cell to gastrula.	Unknown.	Eggs vary in diameter from 96 μ to 192 μ, probably due to fragmentation or fusion of eggs under pressure.
945	24-cells to young veliger.	Unknown.	Ectodermal cap not overgrowing yolk; exogastrulæ and exolarvæ.

II. Eggs Shaken and Fragmented.

No.	Stage.	Experiment.	Left in Normal Sea Water.	Results.
855	1–4 cells.	Shaken, then teased out of capsules.	3 hrs.	Many isolated blastomeres and fragmented eggs undergoing partial cleavage. Figs. 32, 33, 35.
856	1–8 cells.	Teased out of capsules.	12 hrs.	8–30 cells, normal development; a few isolated macromeres show partial cleavage.
857	Ca. 80 cells.	Teased out of capsules.	12 hrs.	Early gastrula; normal.
887	1–8 cells.	Shaken.	8 hrs.	20–29 cell stage of normal eggs; many isolated macromeres show partial cleavage.
888	2–4 cells.	Shaken hard.	15 hrs.	Ca. 50 cells, of normal eggs; many isolated macromeres show partial cleavage, others, not dividing, have large nuclei (synkaryonts).
889	2–4 cells.	Shaken hard.	15 hrs.	Similar to preceding.
890	2–4 cells.	Shaken hard.	24 hrs.	Ca. 68 cells in normal eggs; many isolated macromeres and fragmented eggs, some of them showing partial cleavage.
891	2–4 cells.	Shaken hard.	24 hrs.	Similar to preceding.
892	1–8 cells.	Shaken.	25 hrs.	52–70 cells in normal eggs; many partial eggs.
921	1–4 cells.	Shaken.	2 hrs.	1–8 cells; some isolated macromeres and fragmented eggs. Fig. 31.
922	24 cells.	Shaken.	2 hrs.	Ca. 30 cells; some fragmented eggs.
923	1–24 cells.	Shaken.	4 hrs.	1–36 cells; few eggs not destroyed.
924	1–24 cells.	Shaken.	4 hrs.	1–36 cells; egg fragments.
925	1–30 cells.	Shaken.	4 hrs.	Many isolated blastomeres and egg fragments.
926	1–4 cells.	Shaken.	4 hrs.	A few isolated blastomeres and fragmented eggs, spindles out of position in a few cases.
927	1–2 cells.	Shaken.	4 hrs.	Few eggs, showing few changes.
928	1–4 cells.	Shaken.	6 hrs.	1–8 cells; similar to No. 926.
929	4 cells.	Shaken.	6 hrs.	Few eggs, showing few changes.
930	2 cells.	Shaken hard.	12 hrs.	16–24 cells; few eggs left; a few isolated macromeres.
931	1–8 cells.	Shaken and pressed.	2–12 hrs.	1–24 cells; more than 4 macromeres.
957	2–24 cells.	Shaken.	4 hrs.	Many egg fragments and isolated macromeres, the latter undergoing partial cleavage.
958	2–24 cells.	Shaken.	17 hrs.	24–68 cells; many partial eggs, some showing abnormal yolk cleavage. Figs. 40, 43, 47.
959	1–4 cells.	Shaken.	24 hrs.	1–52 cells; many isolated macromeres showing partial cleavage; in some macromeres cleavage suppressed, but many nuclei and asters. Fig. 44.

III. Effects of Pressure.

No.	Stage.	Experiment.	Duration.	Free in Sea Water.	Results.
849	1–2 cells.	Pressed between slides.	4 hrs.	13 hrs.	16–30 cells; many abnormal cleavages, yolk cleavage being increased in some egg and suppressed in others, depending upon the axis of pressure.
850	1–4 cells.	Pressed between slides.	5½ hrs.	6 hrs.	2–24 cells; many cleavages abnormal in size and direction; yolk cleavage may be increased or suppressed.
851	1 cell.	Pressed between slides.	8 hrs.	11 hrs.	20–24 cells; 1, 2, or many macromeres due to suppression or increase of yolk cleavage; polyasters and multiple nuclei.
852	2–4 cells.	Pressed between slides.	13 hrs.	4 hrs.	8–30 cells; similar to preceding; some blastomeres isolated.
853	1–4 cells.	Pressed between cover glasses.	14½ hrs.	3 hrs.	4–30 cells; many normal eggs; abnormal forms like those in No. 852.
854	1–4 cells.	Pressed between cover glasses.	18 hrs.	4 hrs.	1–30 cells; in some eggs all cleavage suppressed; others show abnormal forms similar to preceding.
884	1–2 cells.	Pressed flat under cover.	3½ hrs.	12½ hrs.	1–30 cells; many isolated blastomeres, fragmented and degenerating eggs.
885	1–2 cells.	Pressed between slides.	4 hrs.	10½ hrs.	20–30 cells; yolk cleavage suppressed (with multiple nuclei) or increased (with multiplication of macromeres).
886	4 cells.	Pressed between slides.	12½ hrs.	1½ hrs.	Many fragmented and degenerating; abnormal cleavages similar to preceding.
893	24 cells.	Pressed between slides.	4 hrs.	½ hr.	Few modifications.
894	1 cell.	Pressed between slides.	4 hrs.	½ hr.	1–2 cells; few modifications.
895	4 cells.	Pressed out of capsules.	4 hrs.	¾ hr.	Few eggs; few modifications.
896	30–40 cells.	Pressed in capsules.	4 hrs.	2 hrs.	Few modifications; eggs faded.
897	1 cell.	Pressed out of capsules.	4 hrs.	½ hr.	Few eggs and much faded.
898	16–24 cells.	Pressed in capsules.	4 hrs.	2 hrs.	Ca. 30 cells; few modifications.
899	16–24 cells.	Pressed in capsules.	4 hrs.	0 hrs.	24–30 cells; eggs packed together and abnormal in form.
900	1–24 cells.	Pressed out of capsules.	4 hrs.	0 hrs.	1–24 cells; macromeres may be abnormal in number, size and position.
901	1 cell.	Pressed out of capsules.	4 hrs.	0 hrs.	1–4 cells; modifications similar to preceding Fig. 48.
902	4–16 cells.	Pressed out of capsules.	4 hrs.	2 hrs.	4–20 cells; similar to No. 900.
903	1 cell.	Pressed out of capsules.	4 hrs.	2 hrs.	1–4 cells; modifications similar to No. 900.
904	1–8 cells.	Pressed in capsules.	4 hrs.	2 hrs.	1–16 cells; macromeres and micromeres may be abnormal in number, size and position. Fig. 55.
905	1 cell.	Pressed out of capsules.	4 hrs.	2 hrs.	1–8 macromeres; few eggs.
906	1–8 cells.	Pressed out of capsules.	4 hrs.	2 hrs.	1–20 cells; a few abnormal cleavage forms. Fig. 30.
907	1 cell.	Pressed out of capsules.	4 hrs.	2 hrs.	1–4 cells; unequal and non-synchronous divisions of macromeres.
908	1–24 cells.	Pressed out of capsules.	4 hrs.	4 hrs.	1–30 cells; exovates on some macromeres.
909	8–24 cells.	Pressed in capsules.	4 hrs.	4 hrs.	30–40 cells; almost all normal.

III. Effects of Pressure.—(*Continued.*)

No.	Stage.	Experiment.	Duration.	Free in Sea Water.	Results.
910	4–20 cells.	Pressed out of capsules.	4 hrs.	4 hrs.	4–24 cells; many isolated macromeres.
911	1 cell.	Pressed out of capsules.	4 hrs.	4 hrs.	1–8 macromeres, which are abnormal in size and position. Figs. 51, 52, 53.
912	4–16 cells.	Pressed in capsules.	4 hrs.	4 hrs.	24–30 cells; normal.
913	1 cell.	Pressed in capsules.	4 hrs.	4 hrs.	1–16 cells; cleavage of yolk suppressed in some eggs, increased in others (1–many macromeres), depending on axis of pressure.
914	4–16 cells.	Pressed in capsules.	4 hrs.	6 hrs.	24–30 cells; few modifications.
915	1 cell.	Pressed in capsules.	4 hrs.	6 hrs.	1–8 macromeres with corresponding micromeres; many exovates and lobes; amitosis-like division figures. Figs. 54, 56, 59, 60, 61, 65.
916	4–8 cells.	Pressed out of capsules.	4 hrs.	6 hrs.	4–24 cells; a few exovates and isolated macromeres.
917	4–16 cells.	Pressed in capsules.	4 hrs.	6 hrs.	24–30 cells; nearly normal.
918	1 cell.	Pressed out of capsules.	4 hrs.	6 hrs.	1–20 cells; many modifications in number, size and position of macromeres. Figs. 45, 46, 58.
919	1 cell.	Pressed out of capsules.	4 hrs.	6 hrs.	Similar to preceding. Fig. 77.
920	4 cells.	Pressed out of capsules.	4 hrs.	6 hrs.	8–24 cells; similar to No. 918.
1,000 (1)	1–2 cells.	Compressorium.	16 hrs.	0 hrs.	16–25 cells; more than 4 macromeres with corresponding micromeres. Fig. 62.
(2)	1–2 cells.	Compressorium.	16 hrs.	6 hrs.	16–30 cells; a few eggs with exovates and more than 4 macromeres. Fig. 63.
(3)	1–2 cells.	Compressorium.	16 hrs.	16 hrs.	52–70 cells; some isolated macromeres, showing partial cleavage. Fig. 67.
1,001 (1)	1–2 cells.	Compressorium.	15 hrs.	0 hrs.	1–24 cells; many isolated macromeres, also eggs with 1–8 macromeres; exovates. Fig. 66.
(2)	1–2 cells.	Compressorium.	15 hrs.	5½ hrs.	1–42 cells; similar to preceding.
(3)	1–2 cells.	Compressorium.	15 hrs.	15½ hrs.	52–70 cells; a few with more than 4 macromeres. Figs. 67, 76.
1,002 (1)	1–2 cells.	Pressed between slides.	5½ hrs.	0 hrs.	1–8 cells; macromeres abnormal in number, size, and position; exovate and isolated macromeres.
(2)	1–2 cells.	Pressed between slides.	5½ hrs.	7 hrs.	8–25 cells; similar to preceding. Fig. 42.
1,003	1–4 cells.	Pressed between slides.	7 hrs.	0 hrs.	2–16 cells; macromeres abnormal in number, size and position; isolated macromeres and and exovates. Figs. 57, 58.
1,004 (1)	1–2 cells.	Compressorium.	7½ hrs.	0 hrs.	1–16 cells; similar to preceding.
(2)	1–2 cells.	Compressorium.	7½ hrs.	7 hrs.	8–40 cells; similar to No. 1,002 (2).

IV. Effects of Electric Current.

1. *Porcelain-Boot Electrodes.*

No.	Stage.	Strength.	Duration.	Normal.	Results.
995 (1)	1–4 cells.	¼ volt (10 dry cells).	50 min.	0 min.	In eggs most affected spindle fibers are gone and chromosomes fused; in resting nuclei chromatin dissolved.
(2)	1–4 cells.	¼ volt.	1½ hrs.	0 min.	Many killed and fragmented; spindle fibers gone, chromosomes fused; nuclei and cytoplasm dislocated as in centrifuged eggs.
(3)	1–4 cells.	¼ volt.	1½ hrs.	0 min.	Similar to preceding.
(4)	1–4 cells.	Control on preceding.		1½ hrs.	Normal 8–16 cell stage.
(5)	1–4 cells.	¼ volt.	1½ hrs.	¾ hr.	Many killed and fragmented; spindle fibers gone and chromosomes fused in eggs most affected.
996 (1)	1–2 cells.	Beginning control.			Normal 1–2 cells; many cytasters in egg during approach of germ nuclei.
(2)	1–4 cells.	½ volt.	15 min.	2 hrs.	2–16 cells, many normal; in some, nucleus, cytoplasm, yolk displaced by convection.
(3)	1–4 cells.	½ volt.	15 min.	5 hrs.	Similar to preceding.
(4)	1–2 cells.	End control.		1½ hrs.	Normal 1–8 cells.
997 (1)	2–8 cells.	Control on 997 (2) and (3).			Normal 2–8 cells.
(2)	2–8 cells.	1 volt.	15 min.	2½ hrs.	Spindle fibers gone and chromosomes fused; nuclei, cytoplasm, yolk displaced as in centrifuged eggs. Figs. 88, 89, 91.
(3)	1–4 cells.	1 volt.	15 min.	30 min.	Similar to preceding. Figs. 80, 81, 85.
998 (1)	52 cells.	4 dry cells.	1¾ hrs.	0 min.	Micromeres spherical; cytoplasm collected on one side of nucleus.
(2)	52 cells.	4 dry cells.	1¾ hrs.	11 hrs.	Spherical micromeres, separate from macromeres—framboisia; spindle fibers gone, chromosomes fused; parts dislocated as in centrifuged eggs. Fig. 93.
(3)	Control.			12¾ hrs.	Normal 68-cell stage.
999 (1)	1–4 cells.	12 dry cells.	50 min.	1½ hrs.	Nearly normal, few eggs penetrated by current; chromatin and cytoplasm stain more faintly than in normal eggs.
(2)	1–4 cells.	12 dry cells.	30 min.	10 min.	Similar to preceding.
(3)	1–4 cells.	12 dry cells.	50 min.	40 min.	Nearly normal; eggs penetrated by current are similar to No. 997 (2).
(4)	1–4 cells.	12 dry cells.	50 min.	3 hrs.	Similar to preceding.
1,120 (1)	1–20 cells.	1 mil. amp.	45 min.	30 min.	Quite normal; current too weak.
(2)	1–20 cells.	1 mil. amp.	45 min.	24 hrs.	Ca. 52 cells; generally normal; large clear nuclei in a few eggs; sphere may be fragmented.
(3)	1–20 cells.	1 mil. amp.	45 min.	24 hrs.	Similar to preceding.
(6)	1–20 cells.	1 mil. amp.	45 min.	46 hrs.	Ca. 80 cells; quite normal.

2. *Graphite-Plate Electrodes.*

(Eggs of normal control mounted on each slide with those of experiment.)

No.	Stage.	Strength.	Duration.	Normal.	Results.
1,100	2–20 cells.	50 mil. amp.	15 min.	0 hrs.	Eggs coagulated; polarity unchanged.
1,101	2 cells.	50 mil. amp.	4 min.	17 hrs.	Ca. 25 cells; polarity unchanged; spindles normal.
1,102	12–20 cells.	40 mil. amp.	5 min.	0 hrs.	Eggs stuck together; no change in nuclei or spindle.
1,103	12–20 cells.	40 mil. amp.	5 min.	0 hrs.	Similar to preceding.
1,104	1–30 cells.	5 mil. amp.	5 min.	0 hrs.	Many eggs ruptured, blastomeres isolated, exovates due to pressure; polar rays and spindle fibers may be faint or lacking. Fig. 68.
1,105	1–8 cells.	5 mil. amp.	5 min.	0 hrs.	Similar to preceding.

IV. Effects of Electric Current.—(*Continued.*)

2. *Graphite-Plate Electrodes.*

No.	Stage.	Strength.	Duration.	Normal.	Results.
1,106	1–8 cells.	5 mil. amp.	5 min.	17 hrs.	Normal eggs 24–40 cell stage; abnormal 1–4 cell stages. Spindles gone, chromosomes fused, polarity changed; polyasters and multiple nuclei; cleavage irregular. Figs. 82–84.
1,107	1–8 cells.	5 mil. amp.	5 min.	25 hrs.	Similar to preceding; many eggs fragmented.
1,108	1–8 cells.	5 mil. amp.	5 min.	60 hrs.	Normal eggs in early gastrula; others fragmented.
1,109	1–8 cells.	5 mil. amp.	2 min.	30 hrs.	52–70 cells; many broken eggs, some polyasters and massed chromatin.
1,110 (1)	1–20 cells.	5 mil. amp.	2 min.	4 hrs.	Many normal; few show effects of pressure; others effects of convection in dislocation of cytoplasm, nuclei, spindles, and in fusion of chromosomes.
(2)	1–20 cells.	5 mil. amp.	2 min.	22 hrs.	Similar to preceding. Fig. 78.
1,111	1st maturation to 4 cells.	5 mil. amp.	1 min.	0 hrs.	Identically like control.
1,112 (1)	1–8 cells.	5 mil. amp.	1 min.	4 hrs.	Chiefly normal; a few show effects of current.
(2)	1–8 cells.	5 mil. amp.	1 min.	22 hrs.	Chiefly normal 29–52 cells; a few show effects of convection in dislocation of parts, faint spindles and fused chromosomes.
1,113 (1)	1–8 cells.	5 mil. amp.	1 min.	30 hrs.	Many normal 52–70 cells; other 1–8 cells, show effects of current.
(2)	1–8 cells.	5 mil. amp.	1 min.	60 hrs.	80–100 cells; similar to preceding.
1,114	Before maturation.	2 mil. amp.	15 min.	5 hrs.	Few eggs and deeply stained; some show effects of current in dislocation of parts.
1,115	1st maturation.	2 mil. amp.	15 min.	5 hrs.	Many killed; a few show effects of current in dissolution of chromosomes and spindles.
1,116	20–30 cells.	2 mil. amp.	10 min.	5 hrs.	Many killed; others show framboisia.
1,117	1–16 cells.	2 mil. amp.	5 min.	3 hrs.	Many eggs fragmented; a few show dislocation of parts; polyasters and irregular cleavage.
1,118	1–20 cells.	2 mil. amp.	5 min.	3½ hrs.	Some show exovates, effects of pressure; others, the effects of convection in dislocation of nuclei and cytoplasm.
1,119	2–20 cells.	2 mil. amp.	5 min.	20 hrs.	Framboisia, scattered blastomeres; many dead.
1,121 (1)	1–2 cells.	5 mil. amp.	10 min.	0 hrs.	Nearly normal; a few tetrasters.
(2)	1–2 cells.	5 mil. amp.	10 min.	3½ hrs.	Cleavage stopped in most eggs; tetrasters; spindles displaced and chromatin dissolved. Figs. 69–75, 87, 90, 92.
(3)	1–2 cells.	5 mil. amp.	10 min.	16 hrs.	Many abnormal cleavages due to pressure; multiple nuclei; eggs without chromatin have disintegrated. Fig. 79.
(4)	1–2 cells end control.			16 hrs.	Normal 24–32 cell stage.
1,122 (1)	1st maturation.	7 mil. amp.	5 min.	0 hrs.	Eggs and spindles normal; graphite plates were probably in contact.
(2)	1st maturation.*	7 mil. amp.	5 min.	1 hr.	Normal second maturation.
(3)	1st maturation.*	7 mil. amp.	5 min.	3 hrs.	Prophase first cleavage, normal.
1,123	1st cleavage.	7 mil. amp.	5 min.	0 hrs.	Normal; graphite plates were probably in contact.
1,140 (1)	1 cell.*	2 mil. amp.	2 min.	5½ hrs.	Fig. 86. Many eggs normal; others have polyasters and multiple nuclei. Some show effects of pressure, others of electric current; in latter nuclear membrane, chromatin, and spindle fibers almost dissolved; chromosomes do not dissolve as readily as resting chromatin; in a few cases nuclei and cytoplasm dislocated, probably by current.
(2)	1 cell.*	2 mil. amp.	2 min.	11 hrs.	Similar to preceding.

IV. Effects of Electric Current.—(*Continued.*)

2. *Graphite-Plate Electrodes.*

No.	Stage.	Strength.	Duration.	Normal.	Results.
1,141 (1)	1–16 cells.*	2 mil. amp.	2 min.	4½ hrs.	1–29 cells; many fragmented eggs showing partial cleavage; chromatic granules scattered throughout the yolk.
(2)	1–16 cells.*	2 mil. amp.	2 min.	10 hrs.	20–48 cells (a few older); eggs generally normal; some isolated blastomeres showing partial cleavage; many lobulated nuclei and karyomeres.
1,142 (1)	1–20 cells.*	1 mil. amp.	5 min.	4 hrs.	1–20 cells; many eggs fragmented, others fused together; cytoplasm not segregated from yolk; chromatin may be dissolved.
(2)	1–20 cells.*	1 mil. amp.	5 min.	8 hrs.	1–29 cells; many normal, others similar to preceding; yolk cleavage may be suppressed, with formation of polyasters, or increased, with formation of many macromeres.

* Water carefully drained off graphite plate; contact through eggs and egg capsules only.

V. Effects of Abnormal Temperature.

No.	Stage.	Experiment.	Duration.	Results.
960	1–4 cells.	Ca. 35° C.	4 hrs.	Eggs degenerating; chromatin of resting nuclei clumped; chromosomal vesicles scattered; cytoplasm vacuolated.
961 (1)	1–8 cells.	Ca 2°–3° C.	4 hrs.	1–8 cells, normal.
(2)	1–8 cells.	Ca 2°–3° C.	16 hrs.	4–8 cells, normal; spheres very distinct. Figs. 100–102.
(3)	1–8 cells.	Ca 2°–3° C.	28 hrs.	8–16 cells, normal; spheres very distinct with peripheral layer of coarse granules.
(4)	1–8 cells.	Ca 2°–3° C.	40 hrs.	4–30 cells; polyasters and multiple nuclei in cells where cleavage furrow was suppressed; sphere less distinct, and sphere granules scattered. Figs. 103–105.
1,170 (1)	1–2 cells.	Ca. 38° C.	1 hr.	Surface tension reduced; eggs very irregular in outline, with all archiplasm drawn into central area or in small masses under cell membrane; no astral rays or spindle fibers; chromosomes scattered. Fig. 94.
(2)	1–2 cells.	Ca. 38° C. Ca. 25° C.*	1 hr. 6 hrs.	Similar to preceding; no development.
1,171 (1)	2–24 cells.	37° C.	½ hr.	Profound changes in structure and orientation of mitotic figures; chromosomes scattered; centrosomes and spindle fibers gone; archiplasm drawn into astral areas, or collected along division walls. Figs. 96, 97.
(2)	2–24 cells.	37° C. Ca. 25° C.*	½ hr. 15 hrs.	Similar to preceding; chromosomes do not form nuclei and may be far away from cytoplasmic areas. Figs. 98, 99.
1,172 (1)	1–24 cells.	36° C.	1 hr.	Similar to 1,171 (1); archiplasm very distinct from surrounding plasma.
(2)	1–24 cells.	36° C. Ca. 23°–25°*	1 hr. 15 hrs.	Similar to 1,171 (2).
1,173 (1)	2–16 cells, a few gastrulæ.	37°	¼ hr.	Surface tension reduced; spindle fibers gone; chromosomes scattered; archiplasm not sharply segregated.
(2)	2–16 cells. Id.	37° Ca. 27°*	¼ hr. 3 hrs.	Scattered chromosomes of preceding have produced numerous karyomeres.
1,174 (1)	1 cell.	37°	¼ hr.	Surface tension reduced; mitotic figures very abnormal; spindle fibers gone; chromosomes scattered.
(2)	1 cell.	37° Ca. 27°*	¼ hr. 3 hrs.	Scattered chromosomes have produced numerous karyomeres. Fig. 95.

* Room temperature.

V. Effect of Abnormal Temperature. (*Continued.*)

No.	Stage.	Experiment.	Duration.	Results.
1,175 (1)	1–8 cells.	33°	¼ hr.	Orientiaton of mitotic figure changed; spindle fibers gone; chromosomes scattered, otherwise normal in appearance.
(2)	1–8 cells.	33° / Ca. 27°*	¼ hr. / 3 hrs.	Irregular cleavages, due to reduced surface tension; many karyomeres, due to scattered chromosomes; mitosis normal at 27°.
1,176 (1)	4–16 cells.	34°–35°	¼ hr.	Sharp segregation of cytoplasm and yolk; archiplasm drawn into central areas and division walls; chromosomes scattered; centrosome and spheres indistinct.
(2)	4–16 cells.	34°–35° / Ca. 23°*	¼ hr. / 3 hrs.	Collection of clear plasma at animal pole and along cleavage furrows; cleavage frequently suppressed; many karyomeres and irregular nuclei, each with a large nucleolus.
(3)	4–16 cells.	34°–35° / Ca. 22°–25°*	¼ hr. / 19 hrs.	Ca. 24–30 cells; cleavages nearly normal, though sometimes suppressed; many scattered chromosomes and karyomeres.
(4)	4–16 cells.	34°–35° / Ca. 22°–25°*	¼ hr. / 27 hrs.	Ca. 52–60 cells; similar to preceding; chromatic connections between daughter nuclei, the result of scattered chromosomes.
(5)	4–16 cells.	34°–35° / Ca. 22°–25°*	¼ hr. / 44 hrs.	Ca. 80–90 cells; many karyomeres and irregular nuclei which persist through many mitoses but do not interfere with regular cleavages.
1,177 (1)	1–2 cells.	33°–34°	½ hr.	Daughter nuclei and clear plasma drawn down into middle of egg along cleavage furrow; latter often suppressed at vegetal pole and not at animal; some scattered chromosomes.
(2)	1–2 cells.	33°–34° / Ca. 22°–25°*	½ hr. / 17 hrs.	Ca. 30–40 cells; second cleavage may be suppressed, and polyasters may be present; many karyomeres, especially in entomeres.

* Room Temperature.

VI. Effects of Ether Added to Sea Water.

No.	Stage.	Strength, Per Cent.	Duration.	Results.
800	1–8 cells.	1	1 hr.	No modifications, except that cytoplasm and yolk are not sharply separated.
801	1–8 cells.	½	5½ hrs.	4–16 cells; similar to preceding. Control in 2–8 cells.
803	1–8 cells.	1	5½ hrs.	4–16 cells; similar to No. 800.
818	2–20 cells.	1	25 hrs.	Ca. 52 cells; archiplasm gathered around sphere or nucleus; chromatin clumped; chromosomes scattered and spindle fibers gone; no signs of amitosis.
819	2–20 cells.	1	25 hrs.	Similar to preceding; control in 52 cell stage.
877	1–8 cells.	3	¼ hr.	Cleavage stopped; yolk and cytoplasm intermingle; archiplasm gathers along cleavage furrows; chromosomes scattered; spindle fibers indistinct.
878	1–8 cells.	3	3 hrs. (Normal S. W. 6 hrs.)	Similar to preceding; sphere granules widely scattered; centrosomes large; chromatin clumped in resting nuclei; archiplasm gathers in cleavage furrows; blastomeres may separate.
1,180 (1)	1–2 cells.	2	2 hrs.	Many lobes and deep furrows in resting stages which bear no constant relations to egg axes or nuclei; clear plasma bounds furrows; mitotic figures approximately normal, spindle fibers distinct.
(2)	1–2 cells.	2	6 hrs.	4–16 cells; many eggs normal; a few show large polar bodies and many macromeres; mitotic figures normal. All ether had evaporated before close of experiment.
1,181 (1)	1–20 cells.	1	1 hr.	Cleavage and mitotic figures entirely normal; eggs stain diffusely.
(2)		1	16 hrs.	16–52 cells; cleavage and mitoses approximately normal; eggs are swollen and stain diffusely; deeply staining granules between yolk spheres.

VII. Effects of Reduced Oxygen Tension.

1. *Sea Water Boiled and Cooled.*

a. In Open Bottles.

No.	Stage.	Duration.	Normal Sea Water.	Results.
935	1–2 cells.	12 hrs.	0 hrs.	16–30 cells, normal.
936	16–24 cells.	12 hrs.	0 hrs.	Ca. 50 cells; normal.
937	24–30 cells.	12 hrs.	0 hrs.	Ca. 64 cells, normal.
938	1 cell.	18 hrs.	0 hrs.	25–60 cells, normal.
939	4–12 cells.	18 hrs.	0 hrs.	52 cells, normal.
940	24–30 cells.	18 hrs.	0 hrs.	Ca. 64 cells, normal.
947	1 cell.	48 hrs.	0 hrs.	1–30 cells; framboisia; fusing eggs; many dead.
948	4–12 cells.	48 hrs.	0 hrs.	52–70 cells; framboisia; isolated macromeres; many dead.
949	24–30 cells.	48 hrs.	0 hrs.	64–86 cells; similar to preceding.
950	1–16 cells.	4 hrs.	0 hrs.	2–20 cells, normal.
951	1–16 cells.	17 hrs.	0 hrs.	48–60 cells, nearly normal; some chromosomes scattered, and some resting nuclei lobulated or multiple.
952	1–16 cells.	24 hrs.	0 hrs.	52–70 cells, nearly normal.
953	1–16 cells.	40 hrs.	0 hrs.	64–86 cells, nearly normal; sometimes only one blastomere of 2-cell stage develops.

b. In Stoppered Bottles.

1,010	1–4 cells.	36 hrs.	0 hrs.	1–4 cells; cleavage stopped; eggs smaller than normal, only 120 μ in diameter; nuclei large, vesicular, with large nucleoli; centrosomes very large; sphere granules widely scattered. Figs. 106–109.
1,011	1 cell.	5 hrs.	0 hrs.	1–4 cells; astral rays withdrawn and spheres very distinct; otherwise typical.
1,012	1–4 cells.	6 hrs.	0 hrs.	1–20 cells, nearly normal.
1,013	2–20 cells.	20 hrs.	0 hrs.	2–20 cells; nuclei large, with chromatin clumped.
1,014	Gastrulæ.	20 hrs.	0 hrs.	No changes.
1,015	1–8 cells.	24 hrs.	0 hrs.	1–30 cells (a few older stages accidentally included); big nuclei with chromatin clumped; spindles faint.
1,016	1–8 cells.	27 hrs.	0 hrs.	1–20 cells; nuclei large and achromatic; nucleoli large; sphere granules scattered. Figs. 112, 114.
1,017	1–8 cells.	48 hrs.	0 hrs.	1–20 cells; big nuclei and nucleoli; chromatin clumped; sphere granules scattered. Figs. 113, 117.
1,018	1 cell to gastrula.	48 hrs.	0 hrs.	1 cell to gastrula; similar to preceding; cleavage stopped in early stages, later stages not so much affected.
1,020	1–20 cells.	20 hrs.	3 hrs.	2–24 cells; normal; no development while in boiled sea water.
1,021	1–20 cells.	24 hrs.	8 hrs.	8–40 cells, normal; no development while in boiled sea water.
1,022	2–20 cells.	20 hrs.	9 hrs.	24–52 cells; similar to preceding.

2. *Partial Atmosphere of Hydrogen.*

No.	Stage.	Hydrogen Stream.	Closed Bottle.	Open Bottle.	Results.
879	1–40 cells.	3 hrs.			1–40 cells; nuclei of older stages normal; of earlier stages, large, achromatic, with large nucleoli.
880	1–30 cells.	4½ hrs.			1–30 cells; same as preceding.
881	1–30 cells.	Control.		4½ hrs.	4–48 cells, normal.
882	1–30 cells.	7½ hrs.			1–30 cells; same as No. 879.
883	1–30 cells.	Control.		7½ hrs.	24–52 cells, normal.
1,023	2–20 cells.	2 hrs.		2 hrs.	2–24 cells; nuclei and nucleoli large, chromatin clumped; few polyasters; centrosomes and spindles distinct. Fig. 115.
1,024	2–20 cells.*	2 hrs. 1 hr.	18 hrs.	3 hrs.	2–24 cells; similar to preceding; centrosomes and spindles unusually distinct.
1,025	2–20 cells.*	1 hr. 1 hr.	18 hrs.	3 hrs.	2–24 cells; similar to preceding. Figs. 110, 111, 117, 118.
1,026	2–20 cells.*	1 hr. 1 hr.	20 hrs.	5 hrs.	No development while in hydrogen; after 20 hrs. in fresh sea water eggs had reached 48–86 cells.
1,027	1–20 cells.	H 60%—Air 40%	12 hrs.		1–20 cells; cleavage stopped; nuclei nearly normal.
1,028	2–4 cells.	H 70%—Air 30%	12 hrs.		2–4 cells; cleavage stopped.
1,029	1–20 cells.	H 70%—Air 30%	24 hrs.		1–20 cells; similar to preceding.

* Eggs from two experiments mounted together.

3. *Stoppered Bottles of Normal Sea Water.*

No.	Stage.	Duration.	Results.
941	2–8 cells.	20 days.	4 cells to veliger; in early stages, division may be permanently halted in metaphase and anaphase; framboisia; exogastrulæ.
946	1–8 cells.	20 days.	Same as preceding.
1,019	1–20 cells.	48 hrs.	1–30 cells; cleavage checked; nuclei large and clear, with chromatin clumped, as in boiled sea water.

VIII. Effects of Carbonic Acid.

No.	Stage.	Sea Water.		Duration.	Results.
		Charged.	Normal.		
1,163	1–8 cells.	1 part	1 part	28 hrs.	Cell membranes usually granular and wrinkled; lobes and spinning threads present; surface tension reduced; nuclear membrane also wrinkled and lobulated, giving appearance of amitosis; chromatin dense and achromatin scanty in resting nuclei; resting spheres lie at surface of cell, as in normal eggs; mitotic figures normal; cleavage very irregular and often suppressed. Figs. 119, 120, 122–129, 131.
1,164	1–8 cells.	1	1	28 hrs.	Same as preceding.
1,165	1–8 cells.	1	1	28 hrs.	Same as preceding.
1,166	1–30 cells.	1	0	28 hrs.	Similar to preceding; resting nuclei much lobulated, as if in amitosis.
1,167 (1)	1 cell.	1	1	7 hrs.	1–8 cells; cell membrane wrinkled; yolk cleavage often suppressed; nuclei of macromeres densely chromatic; mitotic figures normal; positions of spheres, nuclei and cytoplasm dependent upon direction of cell constriction.
(2)	1 cell.	1	1	28 hrs.	20–40 cells; similar to preceding; many abnormal cleavages due to local reductions of surface tension.
1,168 (1)	1–30 cells.	1	1	4½ hrs.	1–30 cells; in addition to preceding modifications chromosomes may be widely scattered and cytoplasm coarsely granular.
(2)	1–30 cells.	1	1	20 hrs.	4–52 cells; similar to preceding; many karyomeres and irregular nuclei.
1,169 (1)	1–2 cells.	1	1	18 hrs.	1–24 cells; cleavage may be normal or very abnormal; some micromeres and nuclei go through center of egg to vegetal pole; many blastomeres lobulated; cleavage sometimes suppressed; eggs often stick together.
(2)	1–2 cells.	1	1	25 hrs.	24–48 cells; macromeres may be separated from one another and micromeres may go through center of egg to vegetal pole.
(3)	1–2 cells.	1	1	42 hrs.	64–68 cells; many eggs fused in pairs; fusion always between entomeres; nuclei always at surface and not buried along line of fusion.
1,169a(1)	1–4 cells.	1	1	3 hrs.	1–4 cells; chromatin clumped in resting nuclei; sphere outlines very distinct, especially on side away from animal pole; chromosomes scattered; in first cleavage yolk lobe and polar bodies are carried in with furrow to *Zwischenkörper*, and no new membrane is formed until after constriction is completed.
(2)	1–4 cells.	1	1	26 hrs.	8–25 cells; cleavage normal in most eggs; suppressed in a few.
(3)	1–4 cells.	1	1	44 hrs.	48–52 cells; normal in most cases; first and second cleavages suppressed in a few eggs.
(4)	1–4 cells.	1	1	50 hrs.	52–64 cells; similar to preceding.
1,169b 1)	1–4 cells.	1	1	6 hrs.	1–8 cells; some cleavages suppressed; many spindles displaced and chromosomes scattered; many spindles distorted; many lobes on cells.
(2)	1–4 cells.	1	1	24 hrs.	1–8 cells; similar to preceding; cells and nuclei lobulated; many scattered chromosomes and karyomeres, suppressed cleavages and distorted spindles.
(3)	1–4 cells.	1	1	24 hrs.	
		Normal	sea water	11 hrs.	8–30 cells; many irregular cleavages with lobulated and separated macromeres.
(4)	1–4 cells.	1	1	24 hrs.	
		Normal	sea water	25 hrs.	30–50 cells; cleavage very abnormal; many eggs fused.
(5)	1–4 cells.	1	1	24 hrs.	
		Normal	sea water	48 hrs.	60–80 cells; very abnormal cleavage; many fused eggs.

IX. Effects of Diluting Sea Water with Fresh Water.

No.	Stage.	Dilution.		Time in		Results.
		Salt.	Fresh.	Dilute.	Normal.	
858	2–4 cells.	1 part	1 part	2 hrs.	14 hrs.	24–30 cells; yolk cleavage sometimes suppressed, polyasters, multiple nuclei; chromosomes may be scattered along spindle and form chromatic connection between daughter nuclei; older stages normal, or nearly so. Figs. 145, 147, 152, 153, 154, 157, 158.
859	2–4 cells.	1	2	1 hr.	4 hrs.	Many eggs bursted and chromatin of nuclei dissolved; no separation between yolk and cytoplasm; chromatic connection between daughter nuclei; nucleoli large. Fig. 141.
870	1 cell.	1	1	½ hr.	1½ hrs.	1–2 cells; few abnormalities.
871	1–4 cells.	1	1	1 hr.	12 hrs.	1–30 cells; many isolated macromeres showing partial cleavage; blastomeres may be abnormal in size, position and quality; yolk cleavage often suppressed; polyasters and multiple nuclei. Fig. 156.
872	1 cell.	1	1	½ hr.	15 hrs.	1–25 cells; cleavage may be adequal and little difference between macromeres and micromeres; yolk cleavage increased; direction of cleavage may be modified; spindles may be degenerate and connective fibers chromatic. Figs. 136, 142, 143.
873	1 cell.	1	1	½ hr.	24 hrs.	Similar to preceding; many eggs fragmented and degenerate.
874	4–20 cells.	1	1	1 hr.	25 hrs.	Ca. 52 cells; a few partial eggs, others normal.
875	1–8 cells.	1	2	½ hr.	7 hrs.	1–24 cells; isolated macromeres; in some cases yolk cleavage suppressed, in others increased; 1-many macromeres; polyasters, degenerate spindles, multiple spheres; tendency to equal cleavage of yolk; enormous polar body. Figs. 39, 132–135, 137–140, 144.
876	4–8 cells.	1	2	½ hr.	20 hrs.	24–32 cells, many normal, others fragmented; chromatic connection between daughter nuclei.
954	2–20 cells.	1	1	3 hrs.	0 hrs.	Few eggs, showing few abnormalities.
955	2–20 cells.	1	1	3 hrs.	14 hrs.	Similar to preceding.
956	2–20 cells.	1	1	2 hrs.	36 hrs.	Ca. 68 cells; many show polyasters, abnormal distribution of chromosomes, multiple nuclei. Fig. 150.
993 (1)	1–4 cells.	1	1	1¾ hrs.	15½ hrs.	24–42 cells; in some eggs yolk cleavage suppressed with formation of polyasters, karyomeres, and multiple nuclei; in others yolk cleavage increased. Figs. 146, 148, 149, 151, 155.
(2)	1–4 cells.	1	1	1¾ hrs.	0 hrs.	1–4 cells; some isolated blastomeres; chromosomes scattered; position and direction of spindles changed.
(3)	1–4 cells.	1	1	1¾ hrs.	27 hrs.	Ca. 52 cells; irregular cleavage; yolk cleavage may be suppressed, giving rise to polyasters, multiple nuclei and discoidal cleavage, or it may be increased, macromeres and micromeres becoming equal in size.
1,182 (1)	1–4 cells.	1	1	2 hrs.	0 hrs.	1–4 cells; no sharp distinction between yolk and cytoplasm; many yolk spheres have escaped through cell membrane; lobes and deep furrows at animal pole; large polar bodies; nuclei large, centrosomes and spheres small and dense; scattered chromosomes and karyomeres; cleavages may be suppressed and nuclei displaced and macromeres separated.
(2)	1–4 cells.	1	1	2 hrs.	18 hrs.	16–52 cells; many normal, others very abnormal, with equatorial and meroblastic cleavages, and with irregular nuclei and karyomeres.
(3)	1–4 cells.	1	1	2 hrs.	28 hrs.	52–70 cells; many normal, others similar to preceding.

IX. Effects of Diluting Sea Water with Fresh Water.—(*Continued.*)

No.	Stage.	Dilution.		Time in		Results.
		Salt.	Fresh.	Dilute.	Normal.	
(4)	1–4 cells.	1 part	1 part	2 hrs.	44 hrs.	100–120 cells; similar to preceding.
(5)	1–4 cells.	1	1	2 hrs.	52 hrs.	Early gastrulæ; many normal; some framboisia; karyomeres in endoderm cells.
1,183 (1)	24–48 cells.	1	1	7½ hrs.	0 hrs.	Large cleavage cavity between macromeres and micromeres; scattered chromosomes, irregular nuclei, daughter nuclei do not become achromatic.
(2)	24–48 cells.	1	1	7½ hrs.	16½ hrs.	40–70 cells; cleavage cavity enormous, micromeres arched over it and nearly separated from yolk; karyomeres, irregular nuclei; dividing cells may contain heaps of peripheral granules.
1,184 (1)	2–52 cells.	1	1	3 hrs.	3½ hrs.	Large cleavage cavity; a few eggs show scattered chromosomes, karyomeres, and lobulated nuclei.
(2)	2–52 cells.	1	1	3 hrs.	23 hrs.	Ca. 52–80 cells; similar to preceding; exogastrulæ.
(3)	2–52 cells.	1	1	3 hrs.	28 hrs.	Ca. 52–80 cells; similar to preceding.
(4)	2–52 cells.	1	1	3 hrs.	52 hrs.	Early gastrula stage; many exogastrulæ.
1,185 (1)	1 cell.	40	60	3 hrs.	0 hrs.	1 cell; many eggs bursted; others are swollen and show little distinction between cytoplasm and yolk; nuclei swollen and achromatic; no mitotic figures.
(2)	1 cell.	40	60	3 hrs.	15 hrs.	1–20 cells; cleavage generally normal; in a few cases macromeres isolated, or cleavage suppressed.
(3)	1 cell.	40	60	3 hrs.	40 hrs.	Ca. 40–50 cells, normal.
1,186 (1)	1–8 cells.	1	1	3 hrs.	15 hrs.	Ca. 8–30 cells; in many eggs yolk cleavage suppressed; some blastomeres abnormal in position or size, others isolated; scattered chromosomes, chromatic connections between daughter nuclei, karyomeres, synkaryonts.
(2)	1–8 cells.	1	1	3 hrs.	39 hrs.	Ca. 40–60 cells; cleavage often abnormal or suppressed; many fused and partial eggs; scattered chromosomes, karyomeres and synkaryonts are abundant.
(3)	1–8 cells.	1	1	3 hrs.	50 hrs.	Ca. 50–70 cells; similar to preceding.
(4)	1–8 cells.	1	1	3 hrs.	64 hrs.	Ca. 70 cells to early gastrula; many partial or fused eggs; scattered chromosomes, karyomeres and synkaryonts.
(5)	1–8 cells.	1	1	3 hrs.	87 hrs.	Early and late gastrulæ; some normal, others abnormal; some eggs fused, others partial; karyomeres and synkaryonts.

X. Effects of Hypertonic Sea Water.

1. *NaCl Added to Sea Water.*

No.	Stage.	Per Cent.	Time in		Results.
			Solution.	Normal S. W.	
804	1–4 cells.	1	4 hrs.	0 hrs.	A spindle forms in connection with each germ nucleus, if the poles lie close together triasters or tetrasters form; no vesicular nuclei. Figs. 159–170, 210.
805	1–4 cells.	2	4 hrs.	0 hrs.	Chromatin clumped in center of nuclear vesicle; achromatin fills nuclear vesicle and in mitosis fills amphiaster; spindles shrunken and no fibers visible; chromosomes scattered; cytasters, but no multipolar spindles. Figs. 183, 189, 190.
806	1–4 cells.	3	4 hrs.	0 hrs.	Chromatin clumped in nuclear vesicle; nuclei and spindles shrunken; cytasters, but no multipolar spindles; connective fibers form spindle, widest in middle; achromatin as in preceding, divides amitotically; no plasma division.
807	1–4 cells.	4	4 hrs.	0 hrs.	Chromatin not clumped, but forms a heavy reticulum, or spireme; nuclei a little shrunken; cleavage stopped.
808	1–2 cells.	1	15½ hrs.	0 hrs.	2–20 cells; yolk cleavage largely suppressed; nuclei densely chromatic, not vesicular; polyasters, karyomeres. Figs. 195, 196.
809	1–2 cells.	2	15½ hrs.	0 hrs.	Chromatin in dense masses; achromatin in numerous separate vesicles, widely scattered, formed from substance of spindles and rays; no spindles; no cleavage. Figs. 184–188.
810	1–4 cells.	3	15½ hrs.	0 hrs.	Chromosomes do not form vesicles, but achromatin of spindle and asters does as in Figs. 79–82; no cleavage. Figs. 178–182.
811	1–2 cells.	4	15½ hrs.	0 hrs.	No cleavage; chromatin and achromatin separate and distinct; chromosomes scattered; spindle of homogeneous achromatin, no fibers; no radiations.
813	1–20 cells.	1	1 hr.	17 hrs.	8–20 cells; blastomeres abnormal in size and position; in resting stage chromatin like spireme; sphere has very definite outline, centrosomes dark and dense in sphere; mitoses few but distinct; chromosomes do not form vesicles, but achromatin and membrane form around them.
814	1–20 cells.	2	1 hr.	17 hrs.	8–25 cells, mostly normal; abnormal only when mitosis has been disturbed; no polyasters, some karyomeres; scattered chromosomes; chromatic connections between daughter nuclei in few cases. Fig. 221.
815	1–20 cells.	3	1 hr.	17 hrs.	8–25 cells; cleavage normal, development stopped only temporarily; mitoses normal; no polyasters.
816	1–20 cells.	4	1 hr.	17 hrs.	Similar to preceding.
821	1–2 cells.	1	16 hrs.	8 hrs.	25–40 cells; cleavage very irregular; yolk cleavage may be suppressed or increased; polyasters and karyomeres.
822	1–2 cells.	2	16 hrs.	8 hrs.	1–8 cells; little cleavage and very irregular; polyasters and karyomeres. Figs. 174, 175, 177, 217.
823	1–2 cells.	3	16 hrs.	8 hrs.	1–2 cells; no cleavage, no asters, no centrosomes or spheres; nuclei may be enormous and chromatic, or small and clear; the latter, which were in mitosis at beginning of exp., have not taken in achromatin, which is scattered as homogeneously colored spherules. Figs. 171–173, 176, 191, 192.
824	1–2 cells.	4	16 hrs.	8 hrs.	1–2 cells; similar to preceding; resting nuclei constricted and lobulated as in amitosis; big nucleoli; astral rays contracted, spindle fibers fused, chromosomes scattered; achromatic spherules widely scattered.

X. Effects of Hypertonic Sea Water.—(*Continued.*)

1. *NaCl Added to Sea Water.*

No.	Stage.	Per Cent.	Time in		Results.
			Solution.	Normal S. W.	
825	1–2 cells.	2	16 hrs.	23 hrs.	1–2 cells; no cleavage; karyomeres, polyasters; some nuclei large, thin walled and achromatic, others contain large, dense nucleolus; many nuclei constricted and lobed as in amitosis. Fig. 202.
827	1–20 cells.	¾	9 hrs.	8 hrs.	Ca. 2–50 cells; cleavage irregular; yolk cleavage usually suppressed, sometimes increased; karyomeres; many polyasters; later stages less modified than earlier ones. Figs. 203, 206.
828	1–20 cells.	1	2 hrs.	6½ hrs.	1–24 cells; very abnormal cleavage; yolk cleavage suppressed, plasma cleavage active; polyasters, scattered chromosomes, karyomeres. Fig. 222.
829	1–20 cells.	1½	9 hrs.	18 hrs.	Ca. 1–60 cells; cleavage very irregular; yolk divides seldom; many polyasters, karyomeres.
830	1–20 cells.	2	9 hrs.	32 hrs.	Ca. 1–70 cells; cleavage nearly suppressed; many polyasters, karyomeres, which stain faintly; clear, unstained nucleoli. Fig. 207.
831	1–20 cells.	3	2 hrs.	6½ hrs.	Ca. 1–30 cells; no polyasters or karyomeres, chromosomes widely scattered; nuclei flattened in polar axis.
832	1–20 cells.	4	2 hrs.	6½ hrs.	1–20 cells; yolk cleavage suppressed; karyomeres, polyasters; nuclei flattened in polar axis; advanced stages nearly normal.
839	1–4 cells.	1	6 hrs.	20 hrs.	Ca. 1–30 cells; yolk cleavage suppressed; polyasters, karyomeres; scattered chromosomes; bunch of micromeres on unsegmented yolk.
840	1–4 cells.	2	6 hrs.	20 hrs.	Ca. 1–30 cells; yolk cleavage suppressed; polyasters, karyomeres; chromosomes widely scattered.
843	1–4 cells.	1	6 hrs.	15 hrs.	30–40 cells; yolk cleavage suppressed; polyasters, karyomeres; more advanced stages normal. Fig. 205.
844	1–4 cells.	2	6 hrs.	15 hrs.	Ca. 2–40 cells; similar to preceding.
861	1–4 cells.	½	13 hrs.	0 hrs.	20–40 cells; almost normal; yolk cleavage occurs; few polyasters.
862	1 cell.	1	4 hrs.	10 hrs.	Ca. 2–24 cells; yolk cleavage more or less suppressed; many polyasters and karyomeres; heaps of micromeres.
863	1–4 cells.	2	2½ hrs.	10 hrs.	1–25 cells; advanced stages normal; yolk cleavage suppressed; many polyasters and heaps of micromeres. Figs. 204, 213.
864	1–4 cells.	3	2 hrs. 3¼ hrs.	10 hrs. 10 hrs.	Ca. 1–30 cells; cleavage irregular; yolk cleavage more or less suppressed; many polyasters and karyomeres Fig. 211.
865	1–4 cells.	4	2 hrs.	10 hrs.	Ca. 1–30 cells; cleavage less irregular than preceding; few polyasters and karyomeres; later stages normal. Figs. 209, 212.
965	20–30 cells.	1	3 hrs.	0 hrs.	20–30 cells; plasma, nuclei and spindles shrunken and plasmolyzed.
966	20–30 cells.	1	16 hrs.	0 hrs.	20–36 cells; little if any cleavage; plasma, nuclei, and spindles much shrunken and plasmolyzed.
967	1–20 cells.	1	16 hrs.	12 hrs.	Ca. 1–40 cells; earlier stages show suppressed, or increased, yolk cleavage; polyasters, and karyomeres; scattered chromosomes, chromatic connections between daughter nuclei; older stages less abnormal.
968	1–20 cells.	1	16 hrs.	24 hrs.	1–64 cells; abnormalities similar to preceding; some eggs fused together, others with isolated macromeres.
969	4–12 cells.	2	3 hrs.	0 hrs.	4–12 cells; plasma, nuclei and spindles shrunken; in resting nuclei chromatin clumped in middle of vesicle of achromatin; in mitosis amphiaster lies in definite area of achromatin; plasma gathers in cleavage furrows.

X. Effects of Hypertonic Sea Water.—(*Continued.*)

1. *NaCl Added to Sea Water.*

No.	Stage.	Per Cent.	Time in		Results.
			Solution.	Normal S. W.	
970	4–12 cells.	2	16 hrs.	0 hrs.	4–12 cells; similar to preceding, but modifications more pronounced.
971	4–12 cells.	2	16 hrs.	12 hrs.	4–12 cells; great numbers of karyomeres and constricted nuclei, polyasters.
972	4–12 cells.	2	16 hrs.	24 hrs.	4–20 cells; very abnormal cleavage; yolk cleavage sometimes suppressed, sometimes increased; many polyasters and karyomeres. Figs. 220, 223.
973	2–20 cells.	3	1 hr.	1 hr.	2–20 cells; nearly normal; few cells show any signs of plasmolysis.
974	2–20 cells.	3	1 hr.	16 hrs.	24–44 cells; mostly normal; in a few eggs yolk cleavage suppressed, polyasters and karyomeres.
975	2–20 cells.	3	1 hr.	24 hrs.	30–52 cells; similar to preceding.
976	2–20 cells.	3	1 hr.	39 hrs.	60–70 cells; almost all normal; a few karyomeres.
977	2–20 cells.	4	1 hr.	1 hr.	2–20 cells; plasma, nuclei, spindles are normal; have recovered from plasmolysis.
978	2–20 cells.	4	1 hr.	16 hrs.	20–50 cells; plasma, nuclei and spindle normal.
979	2–20 cells.	4	1 hr.	24 hrs.	20–60 cells; chiefly normal; a few karyomeres.
980	2–20 cells.	4	1 hr.	39 hrs.	60–70 cells; chiefly normal; a few degenerating mitotic figures which never recovered; few karyomeres.
981	1–20 cells.	5	¾ hr.	2 hrs.	1–20 cells; chiefly normal; few signs of plasmolysis; a few chromatic connections between daughter nuclei.
982	1–20 cells.	5	½ hr. + ¾ hr.	18 hrs.	24–44 cells; chiefly normal; no polyasters or karyomeres.
983	1–20 cells.	5	¾ hr.	24 hrs.	2–52 cells; mainly normal; some earlier stages abnormal, with suppressed or increased yolk cleavage, polyasters and karyomeres.
984	1–20 cells.	5	¾ hr.	40 hrs.	60–70 cells, mainly normal; a few abnormalities of earlier stages similar to preceding.
985	2–20 cells.	6	¾ hr.	2 hrs.	8–24 cells, mainly normal; plasma, nuclei, spheres, spindles show no trace of plasmolysis.
986	2–20 cells.	6	½ hr. + ¾ hr.	18 hrs.	2–40 cells, mainly normal; some early stages show suppression of yolk cleavage, with polyasters and karyomeres; later stages are normal.
987	1 cell.	6	¾ hr.	24 hrs.	1–4 cells; suppressed cleavage, polyasters, karyomeres.
988 (1)	1–4 cells.	1	2 hrs.	0 hrs.	1–4 cells; no cleavage; nuclei and spindles shrunken; achromatin withdrawn from radiations into spindle, leaving isolated portions of achromatin, which become cytasters.
(2)	1–4 cells.	1	4 hrs.	0 hrs.	1–4 cells; similar to preceding.
(3)	1–4 cells.	1	5 hrs.	0 hrs.	1–4 cells; similar to preceding.
989 (1)	1 cell. 2d Maturation	1	4¾ hrs.	0 hrs.	1 cell; nuclei and spindles shrunken; cytasters.
(2)	1–4 cells.	1	4¾ hrs.	0 hrs.	1–4 cells; plasma, nuclei and spindles shrunken; few, if any, cytasters.
(3)	1–4 cells.	1	4¾ hrs.	13 hrs.	1–16 cells; suppressed and unequal cleavage of yolk; polyasters, karyomeres; enormous asters surrounded by many chromosomes.
990 (1)	1–4 cells.	4	2¾ hrs.	13½ hrs.	2–16 cells; scattered chromosomes; chromatic connections between daughter nuclei; polyasters, karyomeres, big nuclei and nucleoli.
(2)	1–4 cells.	1	2¾ hrs.	13½ hrs.	24–44 cells; increased cleavage of yolk.
(3)	1–4 cells.	4	2¾ hrs.	24 hrs.	1–24 cells; yolk cleavage may be suppressed in 1st and 2d cleavages, increased in later cleavages; polyasters, karyomeres; no normal mitoses.
(4)	1–4 cells.	1	2¾ hrs.	24 hrs.	52–60 cells; mostly normal.
(5)	1–4 cells.	1	2¾ hrs.	36 hrs.	68–76 cells; a few karyomeres and polyasters.

X. Effects of Hypertonic Sea Water.—(*Continued.*)

1. *NaCl Added to Sea Water.*

No.	Stage.	Per Cent.	Time in		Results.
			Solution.	Normal S. W.	
(6)	1–4 cells.	4	2¾ hrs.	36 hrs.	4–60 cells; first and second cleavage of yolk may be suppressed; karyomeres, polyasters.
994 (1)	1–20 cells.	1	2¾ hrs.	8 days.	Ca. 100–150 cells; nearly normal; few karyomeres.
(2)	1–20 cells.	1	4 hrs.	0 hrs.	1–20 cells; no cleavage; cytasters; polyasters.
(3)	1–20 cells.	1	4 hrs.	0 hrs.	1–20 cells; plasma, nuclei and spindles shrunken; no cleavage; many cytasters and polyasters.
(4)	1–20 cells.	1	4¾ hrs.	36 hrs.	1–40 cells; very irregular cleavage; karyomeres, polyasters.
(5)	1–2 cells.	1	5 hrs.	0 hrs.	1–2 cells; plasma, nuclei and spindles shrunken; scattered chromosomes; polyasters.
1,187 (1)	1–2 cells.	1	4 hrs.	0 hrs.	1–4 cells; cytasters are present during approach of pronuclei; some furrows suppressed.
(2)	1–2 cells.	1	4 hrs.	19 hrs.	Ca. 30–40 cells; yolk cleavage may be suppressed; macromeres may be isolated; karyomeres.
(3)	1–2 cells.	1	4 hrs.	30 hrs.	Ca. 60–70 cells; similar to preceding.
(4)	1–2 cells.	1	4 hrs.	44 hrs.	Ca. 80–100 cells; karyomeres or lobulated nuclei always occur where yolk cleavage is suppressed.
(5)	1–2 cells.	1	4 hrs.	67 hrs.	Gastrula stages; similar to preceding.

2. *$MgCl_2$ Added to Sea Water.*

No.	Stage.	Per Cent.	Time in		Results.
			Solution.	Normal S. W.	
833	1–2 cells.	2	9 hrs.	9 hrs.	First and second cleavages of yolk suppressed; heap of micromeres on unsegmented yolk; polyasters, karyomeres; very abnormal cleavage. Figs. 200, 208.
834	1–2 cells.	3	9 hrs.	9 hrs.	Similar to preceding. Fig. 199.
835	1–2 cells.	4	9 hrs.	9 hrs.	Similar to preceding; many micromeres large and contain yolk; spindles deep in yolk.
841	1–2 cells.	2	5 hrs.	17 hrs.	Yolk cleavage partially suppressed; heap of micromeres on unsegmented yolk; polyasters, karyomeres; chromosomes scattered.
842	1–4 cells.	4	5 hrs.	17 hrs.	First and second cleavages of yolk largely suppressed; 26–36 cells in eggs which had passed 4-cell stage; heap of micromeres; polyasters, karyomeres. Figs. 197, 218.
845	1–4 cells.	2	4 hrs.	16 hrs.	24–36 cells in eggs which had passed 4-cell stage, nearly normal; if first and second cleavages suppressed, heap of micromeres on yolk.
846	1–4 cells.	4	4 hrs.	16 hrs.	First and second yolk cleavages suppressed; heap of micromeres; polyasters, karyomeres; 24–36 cells of normal types. Figs. 214–216.
866	1 cell.	1	14½ hrs.	0 hrs.	24 cells; normal except that plasma and chromatin are shrunken a little.
867	1–8 cells.	8	¾ hr.	6½ hrs.	First and second yolk cleavages suppressed; polyasters, karyomeres; 16–24 cells in normal types. Figs. 41, 219.
868	1–4 cells.	8	¾ hr.	10½ hrs.	First and second cleavages suppressed; heap of micromeres; polyasters, karyomeres; many nuclei lobed, constricted, double; older stages normal.
991	1–8 cells.	1	18 hrs.	0 hrs.	First and second cleavages suppressed; spindles and nuclei shrunken; ca. 24 cells of normal type. Figs. 198.
992 (1)	1–8 cells.	4	3 hrs.	1 hr.	First and second cleavages suppressed; karyomeres due to failure of chromosomes to fuse.
(2)	1–8 cells.	4	3 hrs.	14½ hrs.	1–2-cell stages have produced very abnormal forms; 2–8-cell stages have produced normal forms with 29–44 cells.
(3)	1–8 cells.	4	3 hrs.	27 hrs.	Similar to preceding; late stages with 64–70 cells; karyomeres.

X. Effects of Hypertonic Sea Water.—(*Continued.*)

3. *KCl Added to Sea Water.*

No.	Stage.	Per Cent.	Time in		Results.
			Solution.	Normal S. W.	
836	1–4 cells.	¾	9 hrs.	35 hrs.	First and second yolk cleavages may be suppressed, with formation of polyasters and karyomeres; after 4-cell stage fewer micromeres than normal may be formed, with nuclei far apart.
837	1–4 cells.		9 hrs.	35 hrs.	1–4 cells; cleavage largely suppressed, constricted and multiple nuclei, with big nucleoli. Figs. 173, 193, 194.
838	1 cell.		9 hrs.	18 hrs.	All cleavage suppressed; lobed, constricted, and multiple nuclei; little distinction between plasma and yolk.
847	1–4 cells.	1½	5 hrs.	16 hrs.	25–42 cells; a few still in 1–4-cell stage; nuclei may be multiple in macromeres and single in micromeres; no sharp distinction between yolk and plasma.
847*a*	1–4 cells.	1½	5 hrs.	16 hrs.	2–24 cells; yolk cleavage and mitosis in macromeres very abnormal; scattered chromosomes, polyasters; karyomeres, especially in macromeres.
		1			

4. *Herbst's Ca-free Sea Water.** 30.0 g. NaCl
.8 KCl
6.6 $MgSO_4$
962.2 dist. water.

No.	Stage.	Per Cent.	Time in		Results.
			Solution.	Normal S. W.	
848	1–20 cells.		18 hrs.	0 hrs.	1–30 cells; plasma, nuclei and spindles somewhat shrunken; cytasters in unsegmented egg, always connected with radiations; chromatin is like a coarse spireme; chromosomes fail to fuse in telophase; karyomeres; polyasters. Fig. 201.

5. *Cane Sugar Added to Sea Water.*

No.	Stage.	Per Cent.	Time in		Results.
			Solution.	Normal S. W.	
869	1 cell.	10	3 hrs.	11½ hrs.	1–24 cells; many eggs broken; early cleavages irregular; scattered chromosomes, karyomeres, polyasters.

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*See note, p. 536.

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XIV. EXPLANATION OF PLATES XLIII–LIX.

All figures represent whole eggs of *Crepidula plana*, fixed, stained, and mounted in balsam. They were drawn at stage level, with camera lucida, under Zeiss' Apochromatic Hom. Immersion Objective 3 mm., Comp. Ocular 4, and represent a magnification of 333 diameters. In the process of reproduction they have been reduced about one-fifth. The polar bodies are in all cases shaded by parallel lines, while the crenated line which appears in most of the figures represents, somewhat diagrammatically, the line of yolk spherules surrounding the cytoplasmic area. The spheres (centrospheres) are shown in dotted outline, as are also the cells and nuclei which lie at lower levels. Only abnormal eggs are represented, though normal eggs are found in many of the experiments.

Reference Letters.

A, B, C, D = Macromeres.
1a–1d = 1st set of micromeres.
2a–2d = 2d set of micromeres.
3a–3d = 3d set of micromeres.
4d = Mesentomere.
Am. = Amphiaster.
As. = Cytaster.
Ch. = Chromatin.
Ch. V. = Chromosomal vesicles.
End. = Endoderm.
F. C. = Follicle cells.
G. V. = Germinal vesicle.
L. = Lobe.
M. = Mesomere.
Memb. = Cell membrane.
N. = Nucleus.
Nl. = Nucleolus.
♀*N* = Egg nucleus.
♂*N* = Sperm nucleus.
Pb = Polar bodies.
PCp = Posterior cell plate.
S. = Sphere.
ShG = Shell gland.
S. G. = Sphere granules.
Sp. = Spindle.
V. = Velum.
Y. = Yolk.
Z. = Zwischenkörper.

PLATE XLIII.

Abnormalities Found in Nature.

Figs. 2–5, 9, 11–13, 15 probably show effects of pressure; figs. 6–8 and 16 and 17 probably show effects of diluted sea water.

Fig. 1. Immature egg probably incapable of maturation; follicle cells attached.

Fig. 2. First maturation division; abnormally large "yolk lobe" near vegetal pole, containing sperm nucleus.

Fig. 3. Enormous lobe at vegetal pole containing a sperm nucleus with sperm sphere attached; the small nucleus on the right is probably an accessory sperm nucleus; the granular body near the animal pole is probably the egg nucleus.

Fig. 4. Egg probably distorted by pressure; egg and sperm nuclei normal but removed from animal pole; abnormal lobe at vegetal pole.

Fig. 5. Egg with abnormally large yolk lobe.

Figs. 6–8. Eggs in which the 1st and 2d yolk cleavages were suppressed; two micromeres have been formed at the animal pole; karyomeres are present; probably the result of diluted sea water.

Fig. 9. Two-cell stage with entire amphiaster in one cell, and no nucleus or centrosome in the other cell. Probably spindle was displaced by pressure, to one side of cleavage plane; nevertheless egg has divided with formation of well marked "Zwischenkörper."

Fig. 10. Two cells; chromosomes scattered around active centers; this would probably give rise to karyomeres in the resting stages.

Fig. 11. Egg in which the 1st cleavage has been stopped and the nuclei, spheres and cytoplasm are out of their normal positions; probably the effect of pressure.

Figs. 12, 13. Eggs with large lobe opposite end of spindle, result of pressure. In fig. 12, the gonomeres are distinct; in fig. 13, the spindle has been pressed out of position and one of the nuclei lies in the cleavage plane and is constricted by it.

Fig. 14. Two-cell stage with gonomeres distinct.

Fig. 15. Two cells, interkinesis, with cell lobes in spindle axes of 2d cleavage.

Fig. 16. Two cells each with a tetraster.

Fig. 17. Four centrosomes, karyomeres, cleavage planes suppressed; the result, probably, of a tetraster.

PLATE XLIV.

Abnormalities Found in Nature.

Figs. 18–26. Show effects probably of pressure; figs. 27–29, of dilute sea water.

Fig. 18. Four-cell stage; the nucleus is entirely lacking in two of the cells, though sphere and "Zwischenkörper" are present. The lobe attached to these cells indicates that the egg was subjected to pressure at the time of the 1st cleavage; since cells do not divide when nuclei are not present it is probable that the nuclei were lost after the 2d cleavage, though there is no indication as to the manner of their disappearance.

Fig. 19. Four-cell stage, showing in the lobes the effects of pressure during the 2d cleavage.

Fig. 20. Third cleavage showing a lobe in the spindle axis of one cell, the result of pressure.

Fig. 21. Third cleavage spindles are present, three in one cell, one in the other. In the latter the spindle axis (*Sp*4) is normal, in the former abnormal; spindle one (*Sp*1) lies at a higher level than spindles two and three (*Sp*2, *Sp*3).

Fig. 22. Five macromeres, the two upper ones normal, the three lower ones abnormal; due to a tetraster in the lower cells.

Fig. 23. Seven macromeres, six of them reaching to the animal pole where they have formed six micromeres of the first set. One of the macromeres ($1D^2$) lies far from the animal pole and does not form a micromere. The nuclei are double or irregular in shape in macromeres $1B$ and $1D'$ and also in the micromeres derived from them.

Fig. 24. Seven macromeres, six of them reaching to the animal pole where they have formed six micromeres of the first set and are forming in lacotropic direction six micromeres of the second set; one micromere $1D^2$ lies at a deep level and forms no micromere; a triaster is present in $1B$, a double nucleus in $1D^2$ and double nuclei and spheres are found in the micromeres $1b$ and $1d$.

Fig. 25. Six macromeres ($2A$–$2D$), five of which are dividing in dexotropic direction to give rise to five micromeres of the third set. There are six micromeres of the second set and twelve of the first with a central cell containing two nuclei unaccounted for. The micromeres of the first set have divided unequally as in normal eggs.

Fig. 26. Three macromeres, one of them (*D*) giving rise to a micromere of the first set in normal direction; the other ($3B$, $3C$) have produced micromeres of the first, second and third sets in normal manner.

Figs. 27–29. Three embryos of the same laying showing the failure of the micromeres to overgrow the macromeres, probably the result of dilution of sea water with fresh water.

Fig. 27. Shows a gastrula with ectomeres and mesomeres (*M*) forming a cap on the entomeres, though in normal eggs the former would have overgrown the latter at this stage.

Fig. 28. View of right side of embryo showing shell gland (*ShG*), posterior cell plate (*PCp*) and velum (*V*) but with endoderm (*End*) protruding through blastopore.

Fig. 29. Embryo similar to the preceding but viewed from anterior pole.

PLATE XLV.

Cleavage of Isolated Blastomeres.

Fig. 30. Exp. 906: Third cleavage in $\frac{1}{2}$ or $\frac{2}{4}$ blastomeres, separated by pressure; the cells are smaller than the normal macromeres, owing probably to loss of yolk during pressure; each cell is dividing dexiotropically as it should in the third cleavage, but the relative positions of spindles and cytoplasmic areas in the two cells have undergone certain changes as may be seen by comparison with fig. 20.

Fig. 31. Exp. 921: $\frac{1}{2}$ or $\frac{2}{4}$ blastomeres, separated by shaking; the spindles are normal in position though division in *B* has been delayed.

Fig. 32. Exp. 855: $\frac{1}{4}$ blastomere, isolated by shaking; the first micromere has been formed and the second is forming in typical manner. Original animal pole indicated by polar bodies.

Fig. 33. Exp. 855: $\frac{1}{4}$ blastomere, isolated by shaking; the first and second micromeres have formed in normal manner, and the former is dividing as in a whole egg. Original animal pole indicated by polar body.

Fig. 34. No. 714: $\frac{2}{4}$ blastomeres, probably separated by pressure; each macromere has given off a micromere in dexiotropic direction, as in whole eggs.

Fig. 35. Exp. 855: $\frac{1}{2}$ or $\frac{2}{4}$ blastomeres, separated by shaking; each has produced a first micromere in dexiotropic and a second in læotropic direction, and the former are dividing in læotropic direction just as in whole eggs. The micromere plate is a continuous one, without breaks.

Fig. 36. No. 711: $\frac{3}{4}$ blastomeres, one macromere having been separated, probably by pressure. Each macromere has formed one micromere in normal fashion, but a gap exists between micromeres 1*c* and 1*a*.

Fig. 37. Exp. 864: $\frac{1}{2}$ or $\frac{2}{4}$ blastomeres, separated by hypertonic sea water and then left in normal sea water 10 hrs. Each macromere has formed three micromeres, and the first and second of these have subdivided in normal fashion. The egg is a whole in the sense only that it shows no gaps where cells are missing.

Fig. 38. No. 715: $\frac{1}{4}$ egg, probably separated by pressure after third cleavage, as shown by the fact that two micromeres of the first set (1*a* and 1*b*) are present.

Fig. 39. Exp. 875: $\frac{3}{4}$ blastomeres, macromere *C* having been destroyed in dilute sea water; the macromeres have given off the first micromeres, and these have subdivided in typical fashion, forming a triangular, but continuous micromere plate.

Fig. 40. Exp. 958: $\frac{3}{4}$ blastomeres, separated by shaking. Cells *A* and *D* have given rise to first and second micromeres in normal manner; *B* has formed only the first micromere and both 1*B* and 1*b* lack nuclei.

Fig. 41. Exp. 867: $\frac{3}{4}$ blastomeres, separated in hypertonic sea water. Typical cleavage of micromeres and macromeres of each quadrant represented, but the cells of one quadrant are wholly lacking.

Fig. 42. Exp. 1002 (2): $\frac{3}{4}$ blastomeres, separated by pressure. Cleavage typical for each quadrant, but delayed in quadrant *B*; the third micromere is just coming off from 2*D*.

Fig. 43. Exp. 958: $\frac{3}{4}$ blastomeres, separated by shaking. The cleavage of these three quadrants *A*, *C*, and *D* is absolutely typical; the cells of the fourth quadrant (*C*) are entirely lacking, but there are no gaps to mark the places from which they have dropped out. Each macromere has produced three micromeres, and in addition *D* has given rise to a fourth, the mesentoblast, $4d(= M^1, M^2)$. The micromeres have each divided in typical manner, giving rise to a cross (stippled cells) with three arms instead of four.

Fig. 44. Exp. 959: $\frac{3}{4}$ blastomeres separated by shaking; the cleavage of each macromere and the subdivisions of each micromere have taken place as in normal eggs.

PLATE XLVI.

Effects of Pressure.

Fig. 45. Exp. 918: Egg pressed during formation of second polar body, which is abnormally large.

Fig. 46. Exp. 918: Egg pressed during first cleavage which was rendered unequal; nuclei abnormally lobulated.

Fig. 47. Exp. 958: Egg shaken during first cleavage. Similar to preceding.

Fig. 48. Exp. 901: Very large yolk lobe at vegetal pole of one of the cells.

Fig. 49. No. 724: Egg probably pressed during the first cleavage; second cleavage spindles abnormally small.

Fig. 50. Exp. 918: Pressed during second cleavage in the direction of the spindle axes; macromeres *A* and *B* have divided normally giving rise to micromeres 1*a* and 1*b*; in macromere *CD* the second cleavage is still incomplete, and the entire amphiaster is abnormally large.

Fig. 51. Exp. 911: Pressed during the first cleavage; three macromeres with multiple nuclei formed probably as result of a triaster.

Fig. 52. Exp. 911: Pressed during second and third cleavages in chief axis of egg; macromeres *C* and *D* with their micromeres approximately normal; macromeres *A* and *B* have divided in abnormal planes giving rise to macromeres $1A^1$ and $1B^1$ instead of micromeres.

Fig. 53. Exp. 911: Pressed during second and third cleavages in chief axis of egg; all the upper tier of cells except 1*c* are abnormally large and are dividing like micromeres of the first set; in $1B^2$, 1*C* and $1D^2$ the direction of division is like that in the formation of the 2d set of micromeres.

FIG. 54. Exp. 915: Pressed during 2d and 3d cleavages in chief axis of egg; macromere *A* divided nearly equally into $1A^1$ and $1A^2$, which are now forming micromeres of the 1st set; macromeres 1*B*, 1*C* and 1*D* are forming micromeres of the second set.

FIG. 55. Exp. 904: Pressed during 3d cleavage, the direction of which was changed from dexiotropic to læotropic in all quadrants except *B*; correspondingly the next cleavage (shown by spindles) is dexiotropic, instead of læotropic as in typical eggs.

FIG. 56. Exp. 915: Pressed in chief axis during the 4th cleavage, the chief result being the enlarged size of 2*a* and 2*c*.

PLATE XLVII.

EFFECTS OF PRESSURE.

In all figures except 57, 65, 66 the axis of pressure was in the direction of the egg axis.

FIG. 57. Exp. 1003: Pressure parallel with the egg axis has produced a linear arrangement of the four macromeres, each of which preserves its original polarity and is dividing to form the first set of micromeres.

FIG. 58. Exp. 1003: Pressure in the chief axis of the egg has led to the formation of the micromeres of the 1st and 2d sets between the macromeres, instead of above them. The micromeres are larger than usual and the 1st set has subdivided giving off "turret" cells two of which ($1b^2$ and $1d^2$) are much larger than usual, while the other two ($1a^2$ and $1c^2$) have been forced to the lower side of the egg.

FIG. 59. Exp. 915: Pressure in the direction of the egg axis has led to the formation of eight macromeres, each of which is giving off in a dexiotropic direction a micromere of the 1st set.

FIG. 60. Exp. 915: Pressure in the egg axis during the 4th cleavage has caused the formation of larger micromeres than normal, especially in quadrants *C* and *D*, indeed the 2d division of *C* is nearly equal, giving rise to two macromeres; in the subdivisions of the 1st set of micromeres the "turret" cells ($1a^2$–$1d^2$) are much larger than usual.

FIG. 61. Exp. 915: In this case the pressure was probably applied after the formation of the 1st set of micromeres which are normal; the 2d set is also normal except in quadrant *A*, where the macromere 1*A* divided nearly equally into macromeres $2A^1$ and $2A^2$, and the former has divided into $2A^1$ and $2a^1$.

FIG. 62. Exp. 1001 (1): Normal except that macromere *C* divided equally at its first division; the right upper half then gave off a micromere of the first set ($1c^1$) which, judging by the shape of the cell, is about to form a "turret" cell as in the other three quadrants.

FIG. 63. Exp. 1004 (2): Pressed during the 3d cleavage, macromeres *A* and *D* divided nearly equally, thus increasing the number of macromeres to six, each of which has formed a micromere of the 1st set, while *C* has produced also a micromere of the 2d set (2*c*).

FIG. 64. Exp. 1003: Pressed during the formation of the 2d set of micromeres, which are much larger than usual; in the subdivision of 1*b* and 1*c* the peripheral products ("turret" cells) have been forced to the lower pole of the egg, and the macromeres have been pushed apart as in fig. 58.

FIG. 65. Exp. 915: Compressed obliquely to the egg axis; macromere *B* being shoved under the micromere plate; macromere *A* formed a first micromere larger than normal, which has divided equally ($1a^1$, $1a^2$), and then gave rise to a second "micromere," which is really a macromere ($2A^1$).

FIG. 66. Exp. 1001 (1): Compressed parallel with the egg axis, *B* and *D* being shoved under the other cells; the 1st and 2d sets of micromeres are nearly normal; at its 2d division *A* divided nearly equally into 3*A* and $3A^1$, each of which has formed a micromere (2*a*, 2*a*) in a dexiotropic direction.

FIG. 67. Exp. 1001 (3): The cleavage is normal except that 4*d* is larger than usual, the result of pressure in the direction of the egg axis; the cells of the ectodermal cross are stippled.

PLATE XLVIII.

EFFECTS OF ELECTRIC CURRENT.

Eggs subjected to electric current (except figs. 76, 77) but probably showing effects of pressure.

FIG. 68. Exp. 1104 (?): 5 mil. amp., 5 min. First maturation spindle; the mitotic figure is much longer than normal, is central in the egg and the spindle fibres, centrosomes and astral rays are either lacking or very faint. The position is probably due to pressure.

FIG. 69. Exp. 1121 (2): 5 mil. amp. 10 min., normal 3½ hrs. Second cleavage spindles abnormal in position, first cleavage furrow incomplete, development stopped.

FIG. 70. Exp. 1121 (2): Similar to preceding.

FIG. 71. Exp. 1121 (2): Similar to preceding.

FIG. 72. Exp. 1121 (2): Similar to preceding.

FIG. 73. Exp. 1121 (2): Two cells, one containing a complete amphiaster but without any chromatin, the other containing two nuclei and one sphere, probably as the result of pressure at the close of the 1st cleavage.

FIG. 74. Exp. 1121 (2): Second cleavage spindle abnormal in position and division delayed in one blastomere.

FIG. 75. Exp. 1121 (2): Three macromeres in a linear series, the middle one containing two separate cytoplasmic areas, nuclei and spheres, the result of the suppression of the first cleavage, as in fig. 72.

FIG. 76. Exp. 1001 (3): A pressure experiment included in this plate by mistake, showing eight macromeres and eight micromeres.

FIG. 77. Exp. 919: Egg subjected to pressure, probably after formation of 1st set of micromeres. In quadrant *B* and *D* the 2d set of "micromeres" are really macromeres.

FIG. 78. Exp. 1110 (2): 5 mil. amp., 2 min., normal 22 hrs. Egg with scattered blastomeres in the stage of the formation of the 2d set of micromeres.

FIG. 79. Exp. 1121 (3): 5 mil. amp., 10 min., normal 16 hrs. Egg in stage of formation of 2d set of micromeres, showing effects of pressure.

PLATE XLIX.

EFFECTS OF ELECTRIC CURRENT.

FIG. 80. Exp. 997 (3): 1 volt, 15 min., normal 30 min. Egg and sperm nuclei are large and contain little chromatin, sphere material in granules, no segregation of yolk and cytoplasm.

FIG. 81. Exp. 997 (3): Similar to preceding.

FIG. 82. Exp. 1106: 5 mil. amp., 5 min., normal 17 hrs.; nuclear membrane dissolved and chromatin clumped; development stopped.

FIG. 83. Exp. 1106: Similar to preceding.

FIG. 84. Exp. 1106: Similar to preceding.

FIG. 85. Exp. 997 (3): Similar to fig. 80, but with nuclear membrane gone.

FIG. 86. Exp. 1140 (1): 2 mil. amp., 2 min., normal 5½ hrs. Chromatin disappearing.

FIG. 87. Exp. 1140 (2): 5 mil. amp., 10 min. Ordinary tetraster.

FIG. 88. Exp. 997 (2): 1 volt, 15 min., normal 2½ hrs. Plasma and nuclei displaced by convection current, as in centrifuged eggs.

FIG. 89. Exp. 997 (2): Similar to preceding.

FIG. 90. Exp. 1121 (2): Chromosomes have disappeared leaving the spindle fibers a little more chromatic than in normal eggs.

FIG. 91. Exp. 997 (2): 1 volt, 15 min., normal 2½ hrs. Chromatin largely dissolved and displaced toward lower pole; in right cell long strands of cytoplasm.

FIG. 92. Exp. 1121 (2): 5 mil. amp., 10 min., normal 3½ hrs. Spindle and chromosomes disappearing in left cell; others normal.

FIG. 93. Exp. 998 (2): 4 dry cells 1¾ hrs., normal 11 hrs. Evidently egg was in an advanced stage (ca. 42 cells) at the time of the experiment. Although the cells are not dead, the micromeres are rounded (framboisia) and many have dropped off.

PLATE L.

EFFECTS OF ABNORMAL TEMPERATURE.

FIG. 94. Exp. 1170 (1): Ca. 38° C. 1 hr.; egg irregular in outline, with archiplasm withdrawn into amphiaster, and into the surface layer. First maturation amphiaster irregular in shape and chromosomes scattered; sperm nucleus near vegetal pole.

FIG. 95. Exp. 1174 (2): 37° C. ¼ hr., room temp. (27°) 3 hrs.; first polar body very large; chromosomes of second maturation division have formed karyomeres; sperm nucleus near animal pole.

FIG. 96. Exp. 1171 (1): Ca. 35° C. ½ hr.; 2-cell stage, showing dense aggregation of archiplasm around nuclei and spheres, with different kinds of cytoplasm in other parts of cell.

FIG. 97. Exp. 1171 (1): Similar to preceding; second cleavage spindles greatly modified; chromosomes scattered; archiplasm gathered in spindle areas and division wall.

FIG. 98. Exp. 1171 (2): Ca. 35° C. ½ hr., room temp. (ca. 24°–26°) 15 hrs.; the archiplasm has collected in central areas in each cell and in division walls; chromosomes are clumped and thrown out of cytoplasmic areas.

FIG. 99. Exp. 1171 (2): Similar to preceding.

FIG. 100. Exp. 962: On ice 16 hrs.; the spheres of the third cleavage are unusually distinct and the scattered sphere granules of the second cleavage (in the micromeres) are very large.

FIG. 101. Exp. 962: The spheres have a definite boundary, stain more deeply than usual and look almost like nuclei.

FIG. 102. Exp. 962: A later stage, with spheres similar to those shown in fig. 101.

FIG. 103. Exp. 964: On ice 40 hrs.; the sphere granules are especially large.

FIG. 104. Exp. 964: Similar to preceding.

FIG. 105. Exp. 964: Similar to preceding; many of the sphere granules are vesicular.

PLATE LI.

EFFECTS OF DECREASED OXYGEN TENSION.

FIGS. 106–109. Exp. 1010: Eggs placed for 36 hrs. in sea water which had been boiled to drive off contained gases, and then cooled; all development was completely stopped, but eggs were not killed; chromatin in the resting nuclei is collected into one or more masses; spindle fibres are distinct but astral rays are lacking; centrosomes and sphere granules are vesicular. The eggs used in this experiment were much smaller than normal, being only 120 μ in diameter.

FIGS. 110–111. Exp. 1025: Eggs left for 18 hrs. in a stoppered bottle of sea water, through which hydrogen had been run for 1 hr.; development completely stopped; nuclei and nucleoli large, little chromatin.

FIG. 112. Exp. 1016: Eggs placed for 27 hrs. in sea water which had been boiled and cooled; similar to preceding, development stopped.

FIG. 113. Exp. 1017: Eggs left for 48 hrs. in stoppered test tube of boiled and cooled sea water; development completely stopped; sphere granules prominent.

FIG. 114. Exp. 1016: Same as fig. 112; nuclei with little chromatin; sphere granules prominent.

FIG. 115. Exp. 1023: Eggs subjected to atmosphere of hydrogen for 2 hrs. and then left in open bottle for 2 hrs.; development stopped; eggs similar to all others subjected to decreased oxygen tension.

FIG. 116. Exp. 1017: Same as in fig. 113: The spindles are small, deep-staining and without astral rays; the chromosomes are arranged in a ring around the spindles.

FIGS. 117–118. Exp. 1025: Eggs left for 18 hrs. in stoppered bottle of sea water through which hydrogen had been run for 1 hr.; eggs similar to fig. 115; in fig. 118 there is an area of yolk (*Y*) around the upper poles of the spindles.

PLATE LII.

EFFECTS OF CARBONIC ACID.

Eggs in 1–8-cell stage left for 28 hrs. in sea water ½ saturated with CO_2.

FIG. 119. Exp. 1163: Egg showing the individually distinct chromosomal vesicles of the maturation divisions; also the cell membrane separated from the subjacent egg substance.

FIG. 120. Exp. 1163: Eggs showing five protoplasmic cells (one of them with four nuclei) on the unsegmented yolk.

FIG. 121. Exp. 1164: Side view of an egg similar to the preceding.

FIG. 122. Exp. 1163: The second polar body is abnormally large; an accessory aster (*S*) lies in the yolk; the division of the nucleus in the 1st cleavage has taken place normally, though the spheres are prevented from moving to their normal positions above the nuclei by the presence of the large polar body; the cleavage furrow cuts into the egg from the animal pole side only, and ends in a "cleavage head" as in cœlenterate eggs.

FIG. 123. Exp. 1163: The *C* and *D* quadrants are entirely normal; in the blastomere *AB*, the nucleus divided but the cell did not; these two nuclei in an undivided cell gave off a single blastomere of the first set (1*ab*) with large lobulated nucleus, the nuclei, spheres and cytoplasmic areas of the cell *AB* then came to lie at opposite sides of the macromere and each divided independently giving rise to a second micromere (2*a*, 2*b*) which is nearly normal.

FIG. 124. Exp. 1163: There are three macromeres one of which contains a perfect spindle but no chromatin; another contains a polyaster and has given off a large micromere with three nuclei; the third contains a single nucleus which is smaller than normal and has given off in reversed cleavage a 1st and a 2d micromere, the former of which is dividing.

FIG. 125. Exp. 1163: The first cleavage furrow failed to appear though the nuclei divided; at the 2d cleavage each nucleus with its adjacent oöplasm gave off a smaller macromere (*B* and *D*), leaving macromeres *A* and *C* still undivided; each of these four macromeres has given off a micromere of the 1st set.

FIG. 126. Exp. 1163: Three macromeres one of which contains several centrosomes and spheres (*S*) but no nucleus; another contains a bifurcated spindle and a normal one and has just given off two micromeres one on the right and one on the left; the other macromere contains a single nucleus and sphere and has just given off a micromere on the right; two large micromeres with abnormal nuclei occupy the center of the micromere field. There is a general resemblance of this egg to that shown in fig. 124.

FIG. 127. Exp. 1163: Side view of egg with two macromeres and several micromeres. Strands of protoplasm run from the polar bodies to the micromeres and from one of the latter to a macromere, suggesting the "spinning" activities of other eggs; lobes are also found on several cells.

FIG. 128. Exp. 1163: Two macromeres, each with two nuclei and two or more spheres; in the second cleavage the nuclei divided but the cell-body did not; in the third cleavage there was probably a triaster in each macromere, since only two micromeres of the first set were formed (1*ab*, 1*cd*) each with multiple nuclei; in the fourth cleavage each macromere contained two separate spindles and gave off two separate micromeres (2*a*, 2*b*, 2*c*, 2*d*) of the second set; the nuclei in the macromeres are so well separated that it is probable that at the next cleavage two independent spindles would form in each macromere and would lead to the formation of four micromeres of the third set.

FIG. 129. Exp. 1163: Macromeres *A* and *B* did not separate at the 2d cleavage, but each has given rise to three micromeres forming a typical micromere plate, though the direction of division in *A* and *B* has sometimes been atypical.

FIG. 130. Exp. 1164: Irregular cleavage mass in which it is not possible to identify many cells. Several of the cells show loose membranes and lobes.

FIG. 131. Exp. 1163: One of the macromeres (*D*) was separated from the other three, but each has given rise to three micromeres which have subdivided in normal manner, the micromeres formed from *D* lying on the right of the micromere plate formed from the other macromeres.

PLATE LIII.

EFFECTS OF DILUTED SEA WATER.

In figs. 132–135, 137–140, 144 the dilution was one part sea water to two parts fresh water; in all other cases the sea water was diluted with equal parts of fresh water. With higher dilutions the blastomeres tend to separate but do not swell appreciably.

FIG. 132. Exp. 875: Second polar spindle at animal pole; sperm nucleus has formed a spindle (♂*Sp*); the homogeneous chromatic sphere below this may represent an accessory sperm nucleus (♂*N*).

FIG. 133. Exp. 875: First cleavage spindle; the seven chromatic spheres may represent accessory sperm nuclei (♂*N*).

FIG. 134. Exp. 875: Enormous second polar body containing large nucleus and yolk; two nuclei and accessory sperm nucleus (♂*N*) in egg.

FIG. 135. Exp. 875: Probably ½ blastomere containing polyaster and with a micromere which has just divided.

FIG. 136. Exp. 872: Three blastomeres showing reversed polarity, the spheres, nuclei and cytoplasmic areas lying at the pole opposite the polar bodies; one sphere is found in each cell but in the two larger ones the nuclei are multiple.

FIG. 137. Exp. 875: Two macromeres, one containing a triaster, the other a tetraster; the two micromeres are normal except for their large size.

FIG. 138. Exp. 875: Similar to the preceding.

FIG. 139. Exp. 875: Side view of an egg similar to figs. 137, 138.

FIG. 140. Exp. 875: Macromeres *A* and *B* have not divided and the chromosomes are irregularly scattered in the spindle; macromeres *C* and *D* have divided normally giving rise to first and second micromeres and the first set are subdividing normally.

FIG. 141. Exp. 859: Chromosomes were scattered along the spindle during the third cleavage and have given rise to chromatic connections between daughter nuclei, which resemble amitoses.

FIG. 142. Exp. 872: The micromeres are larger than usual (two of them contain yolk) and they have caused a separation of *A*, *B*, from *C*, *D*.

FIG. 143. Exp. 872: The micromeres are larger than usual and contain yolk; the macromeres are separated and one which has just divided (*Y*, *Y*) contains yolk but no cytoplasmic areas; the chromosomes are here scattered along the spindle axis, thus forming a chromatic connection.

FIG. 144. Exp. 875: ⅔ blastomeres, each of which has given rise to one micromere, which has subdivided; the macromeres contain spindles along which the chromosomes are scattered irregularly.

PLATE LIV.

EFFECTS OF DILUTED SEA WATER.

In all experiments represented on this plate sea water was diluted with equal parts of distilled water.

FIG. 145. Exp. 858: Several micromeres have been formed but the yolk has not divided; three of the cells contain several nuclei and spheres, the result probably of polyasters, and one contains a tetraster.

FIG. 146. Exp. 993 (1): Similar to the preceding; the protoplasmic micromeres are partly constricted from the yolk.

FIG. 147. Exp. 858: Exogastrula; similar to the preceding but of a more advanced stage; the multinucleate yolk cell is uncovered by the ectoderm.

FIG. 148. Exp. 993: Similar to the preceding.

FIG. 149. Exp. 993: Side view of an egg placed in diluted sea water in the 2-cell stage; the second cleavage of the yolk was suppressed, but several micromeres have been formed from each macromere.

FIG. 150. Exp. 956: Egg similar to the preceding, viewed from the animal pole; each macromere contains a large quadripartite nucleus and has given rise to twelve micromeres, which cannot be individually identified.

FIG. 151. Exp. 993: Isolated ½ blastomere, the yolk cell has not divided, but contains several nuclei and has given rise to nine micromeres.

FIGS. 152, 153. Exp. 858: Top and side views of eggs which were placed in diluted sea water after formation of the 1st set of micromeres; several dividing cells contain triasters or tetrasters and the chromosomes are widely scattered; chromatic connections between daughter nuclei are falsely suggestive of amitosis.

FIG. 154. Exp. 858: Side view of egg placed in diluted sea water after formation of the three sets of micromeres which are approximately normal; scattered chromosomes have given rise to chromatic connections between daughter nuclei.

FIG. 155. Exp. 993: Isolated ⅔ blastomeres which have produced a ⅔ micromere plate; the macromere 4*D* has given off the mesentoblast 4*d* which is now dividing in normal manner.

FIG. 156. Exp. 871: The 1st set of micromeres have divided twice in normal directions, as indicated by the arrows, giving rise to twelve micromeres; in the formation of the 2d set of micromeres the division of the macromeres was approximately equal.

FIGS. 157, 158. Exp. 858: Eggs in which the nuclear division at the 2d cleavage took place normally, but in which the cell body did not divide; three quartets of micromeres were formed and have subdivided in approximately normal manner, although there are only two separate macromeres. The 4th quartet cells 4*d* and 4*c* form simultaneously from the undivided macromere *CD*, though in normal eggs 4*d* (the mesentoblast) forms at the 24-cell stage, while 4*c* (an entoblast) does not form until the 52-cell stage.

PLATE LV.

Effects of Hypertonic Sea Water.

All eggs shown on this plate are from Exp. 804, and were subjected to 1 per cent. NaCl in sea water for 4 hrs.

Figs. 159–163. The sperm nucleus lies in a small area of cytoplasm near the lower pole; the egg nucleus lies in a larger area of cytoplasm at the animal pole; various stages in the formation of the egg spindle are shown.

Fig. 164. Two spindles, probably those of egg and sperm, are joined at one pole.

Figs. 165, 166. Tetrasters, probably formed from the egg and the sperm spindles.

Fig. 167. Two spindles, probably those of the egg and the sperm, joined at one pole.

Fig. 168. Two spindles, probably those of the egg and sperm, quite separate.

Figs. 169, 170. Tetrasters in different phases of the separation of the chromosomes.

PLATE LVI.

Effects of Hypertonic Sea Water.

Fig. 171. Exp. 823: 3 per cent. NaCl, 16 hrs., normal 8 hrs. Egg nucleus very small and clear with chromosomes persistent within vesicle and egg centrosome outside vesicle; the sperm nucleus is enormous and contains much chromatic sap.

Fig. 172. Exp. 823: Similar to the preceding.

Fig. 173. Exp. 837: 1 per cent. KCl, 9 hrs., normal 35 hrs. Development has been stopped but the egg is not dead; the germ nuclei are very large and achromatic; small achromatic spherules lie in the cytoplasm.

Fig. 174. Exp. 822: 2 per cent. NaCl, 16 hrs., normal 8 hrs. Achromatin in large and small vesicles in the cytoplasm; germ nuclei normal.

Fig. 175. Exp. 822: The germ nuclei are broken up into many separate vesicles, each with a chromatic nucleolus.

Fig. 176. Exp. 823: Two-cell stage from same experiment as figs. 171, 172; nuclei very large and achromatic.

Fig. 177. Exp. 822: Side view of egg in 2-cell stage, each cell containing a large sphere (*S*) and one or more chromatic and two or three achromatic nuclear vesicles.

Fig. 178, 179. Exp. 810: 3 per cent. NaCl, 15 hrs.: Side views of egg in 2-cell stage showing the chromatin massed within the nuclear vesicle; the latter are elongated along the line of the former spindle axis.

Figs. 180–182. Same experiment as preceding; 4-cell stages from animal pole.

Fig. 180. In one half of egg the remains of the 2d cleavage spindle are still visible and the chromatin has formed no nuclear vesicle; in the other half the nuclear vesicles are elongated along the line of the spindle axis, the chromatin being massed at the ends of the vesicle nearest the spheres.

Fig. 181. Nuclear vesicles elongated along the spindle axis are present in three of the cells, and in each the chromatin is massed at the end of the vesicle nearest the sphere; in the fourth cell no nuclear vesicle is present, but traces of spindle fibres may be seen.

Fig. 182. In all four cells the nuclear vesicles are rounded and the chromatin is massed near the center of each vesicle.

PLATE LVII.

Effects of Hypertonic Sea Water.

Figs. 183–185 were in 1-cell stage at beginning of experiment; Figs. 186–196 were in 2-cell stage.

Fig. 183. Exp. 805: 2 per cent. NaCl, 4 hrs.; in both egg and sperm nuclei the chromatin is aggregated into a dense mass in the center of the nuclear vesicle; there are many cytasters near the sperm nucleus.

Fig. 184. Exp. 809: 2 per cent. NaCl, 15 hrs.; the chromatic and achromatic parts of the germ nuclei are in separate vesicles.

Fig. 185. Exp. 809: Similar to the preceding; a double cytaster is present near the germ nucleus.

Fig. 186. Exp. 809: 2 per cent. NaCl, 15 hrs.; the chromatic and achromatic parts of the nucleus are in separate vesicles; the achromatic vesicles are numerous and scattered.

Fig. 187. Exp. 809: Side view of egg similar to preceding.

Fig. 188. Exp. 809: Egg similar to the preceding showing two principal achromatic vesicles (*Ach*) and many smaller vesicles or sphere granules.

Figs. 189, 190. Exp. 805: 2 per cent. NaCl, 4 hrs.; the 2d cleavage spindles are much shrunken in size; the archiplasm around them is much condensed while many small radiating masses of archiplasm are left along the astral radiations as cytasters.

Figs. 191, 192. Exp. 823: 3 per cent. NaCl, 16 hrs., normal 8 hrs.; top and side views of eggs showing in addition to the principal masses of chromatin (*Ch*) very numerous granules or spherules which probably represent scattered achromatic material (*Ach*).

Figs. 193, 194. Exp. 837: 1 per cent. KCl, 9 hrs., normal 36 hrs.; the numerous karyomeres have begun to absorb achromatin and to fuse together.

FIGS. 195, 196. Exp. 808: 1 per cent. NaCl, 15 hrs.; top and side views of eggs with two macromeres and two micromeres, each with many masses of chromatin (karyomeres) and several spheres or asters.

PLATE LVIII.

EFFECTS OF HYPERTONIC SEA WATER.

All eggs represented on this plate were put into hypertonic solutions in the 1-cell stage, and with the exception of fig. 197 none of them show division of the yolk.

FIG. 197. Exp. 842: 4 per cent. $MgCl_2$, 5 hrs., normal 17 hrs.; the two cells at the upper pole are probably enormous polar bodies, both of which contain mitotic figures.

FIG. 198. Exp. 991: 1 per cent. $MgCl_2$, 18 hrs.; one large cell (macromere) contains all the yolk, two smaller cells (micromeres) are purely protoplasmic; both macromeres and micromeres contain many nuclei (karyomeres), the chromatin of each being condensed into one or two masses.

FIG. 199. Exp. 834: 3 per cent. $MgCl_2$, 9 hrs., normal 9 hrs.; both macromere and micromere contain mitotic figures with many poles and scattered chromosomes; sphere granules at the animal pole of the micromere.

FIG. 200. Exp. 833: 2 per cent. $MgCl_2$, 9 hrs., normal 9 hrs.; resting stage following a division stage like that of the preceding figure.

FIG. 201. Exp. 838: Herbst's Ca-free sea water, 18 hrs.; micromere and macromere containing many nuclei and cytasters.

FIG. 202. Exp. 825: 2 per cent. NaCl, 16 hrs., normal 23 hrs.; two spheres and many scattered nuclei (karyomeres) in both macromere and micromere.

FIG. 203. Exp. 827: $\frac{3}{4}$ per cent. NaCl, 9 hrs., normal 8 hrs.; many asters and scattered chromosomes in the macromere and in one of the micromeres.

FIG. 204. Exp. 863: 2 per cent. NaCl, $2\frac{1}{2}$ hrs., normal 10 hrs.; similar to the preceding; scattered spindles and chromosomes; three small micromeres (lobes) budding off from the macromere; sphere granules at the animal pole of the micromeres.

FIG. 205. Exp. 843: 1 per cent. NaCl, 6 hrs., normal 15 hrs.; several micromeres, three of them containing several nuclei or groups of chromosomes; the macromere contains many nuclei (karyomeres).

FIG. 206. Exp. 827: $\frac{3}{4}$ per cent. NaCl, 9 hrs., normal 8 hrs.; macromere and micromeres containing many karyomeres and asters.

FIG. 207. Exp. 830: 2 per cent. NaCl, 9 hrs., normal 32 hrs.; macromeres and micromeres containing a large number of karyomeres or asters; sphere granules under the polar body.

FIG. 208. Exp. 833: 2 per cent. $MgCl_2$, 9 hrs., normal 9 hrs.; many nuclei (karyomeres) and spheres in each cell.

PLATE LIX.

EFFECTS OF HYPERTONIC SEA WATER.

Eggs represented in figs. 209–218 were in the 2-cell stage when the experiments began, and in none of them did the yolk undergo any subsequent cleavage; figs. 219–223 were in the 4-cell stage at the beginning of the experiment.

FIG. 209. Exp. 865: 4 per cent. NaCl, 2 hrs., normal 10 hrs.; the nuclear division at the 2d cleavage occurred regularly but the cell division was suppressed, thus leaving two nuclei of normal appearance, in each cell; at least three spheres are present in the left cell.

FIG. 210. Exp. 804: 1 per cent. NaCl, 4 hrs.; partial suppression of the 2d cleavage furrow which is limited to a shallow furrow on the animal pole side of the egg; the nuclei are irregular and densely chromatic.

FIG. 211. Exp. 864: 3 per cent. NaCl, 3 hrs., normal 10 hrs.; the 2d cleavage spindles have the position of the 3d cleavage spindles of normal eggs; the chromosomes are scattered abnormally on the spindles.

FIG. 212. Exp. 865: 4 per cent. NaCl, 2 hrs., normal 10 hrs.; the two macromeres have each given off a first and a second micromere, the first by dexiotropic and the second by læotropic division, as in normal eggs. Each of the first micromeres contain a single nucleus and sphere; the second micromeres and the macromeres contain several spheres and karyomeres or groups of chromosomes.

FIG. 213. Exp. 863: 2 per cent. NaCl, $2\frac{1}{2}$ hrs., normal 10 hrs.; the first set of micromeres have been formed in dexiotropic direction, as in normal cleavage; the macromeres are dividing again with double spindles or tetrasters.

FIG. 214. Exp. 846: 4 per cent. $MgCl_2$, 4 hrs., normal 16 hrs.; the two macromeres are separated by a group of micromeres which have formed along both sides of the 1st cleavage plane; the polarity of each half thus appears to have been changed, the centers of the ectodermal pole being the surface of contact between the two halves; this may be due, in part, to the outward rotation of the macromeres at the vegetal pole and their inward rotation at the animal pole.

FIG. 215. Exp. 846: 4 per cent. $MgCl_2$, 4 hrs., normal 16 hrs.; side view of an egg with two macromeres and six micromeres; the two original micromeres of the first set have subdivided as indicated by the arrows, the other two micromeres are of the 2d set; all the micromeres contain karyomeres; the macromeres contain chromosomes scattered apparently, along the line of the 1st cleavage spindle.

FIG. 216. Exp. 846: Egg from same experiment as the preceding; the nuclei at the vegetal pole are probably derived from chromosomes which were scattered along the first cleavage spindle as in fig. 215.

FIG. 217. Exp. 822: 2 per cent. NaCl, 16 hrs., normal 8 hrs.; irregular and unequal 2d cleavage with several karyomeres of varying size in each cell.

FIG. 218. Exp. 842: 4 per cent. $MgCl_2$, 5 hrs., normal 17 hrs.; the divisions of the cell body at the 2d cleavage were suppressed in the left half, but two micromeres are arising in normal manner from this half; several accessory asters are present in this half which have served to scatter the chromosomes. The right half of the egg is quite normal.

FIG. 219. Exp. 867: 8 per cent. $MgCl_2$, $\frac{3}{4}$ hr., normal $6\frac{1}{2}$ hrs.; the 3d cleavage was very irregular and has given rise to a large number of karyomeres, and spheres which are in division in three quadrants of the egg.

FIG. 220. Exp. 972: 2 per cent. NaCl, 16 hrs., normal 24 hrs.; second quartet formation; karyomeres or polyasters in each of the cells.

FIG. 221. Exp. 814: 2 per cent. NaCl, 1 hr., normal 17 hrs.; second quartet formation; karyomeres and spheres in every cell.

FIG. 222. Exp. 828: 1 per cent. NaCl, 2 hrs., normal $6\frac{1}{2}$ hrs.; second quartet formation; karyomeres and polyasters in every cell.

FIG. 223. Exp. 972: 2 per cent. NaCl, 16 hrs., normal 24 hrs.; karyomeres (and asters) in every cell; all nuclei are vesicular and contain achromatin as well as chromatin.

PLATE XLIII.

Abnormalities Found in Nature.

Figs. 2–5, 9, 11–13, 15 probably show effects of pressure; figs. 6–8 and 16 and 17 probably show effects of diluted sea water.

Fig. 1. Immature egg probably incapable of maturation; follicle cells attached.

Fig. 2. First maturation division; abnormally large "yolk lobe" near vegetal pole, containing sperm nucleus.

Fig. 3. Enormous lobe at vegetal pole containing a sperm nucleus with sperm sphere attached; the small nucleus on the right is probably an accessory sperm nucleus; the granular body near the animal pole is probably the egg nucleus.

Fig. 4. Egg probably distorted by pressure; egg and sperm nuclei normal but removed from animal pole; abnormal lobe at vegetal pole.

Fig. 5. Egg with abnormally large yolk lobe.

Figs. 6–8. Eggs in which the 1st and 2d yolk cleavages were suppressed; two micromeres have been formed at the animal pole; karyomeres are present; probably the result of diluted sea water.

Fig. 9. Two-cell stage with entire amphiaster in one cell, and no nucleus or centrosome in the other cell. Probably spindle was displaced by pressure, to one side of cleavage plane; nevertheless egg has divided with formation of well marked "Zwischenkörper."

Fig. 10. Two cells; chromosomes scattered around active centers; this would probably give rise to karyomeres in the resting stages.

Fig. 11. Egg in which the 1st cleavage has been stopped and the nuclei, spheres and cytoplasm are out of their normal positions; probably the effect of pressure.

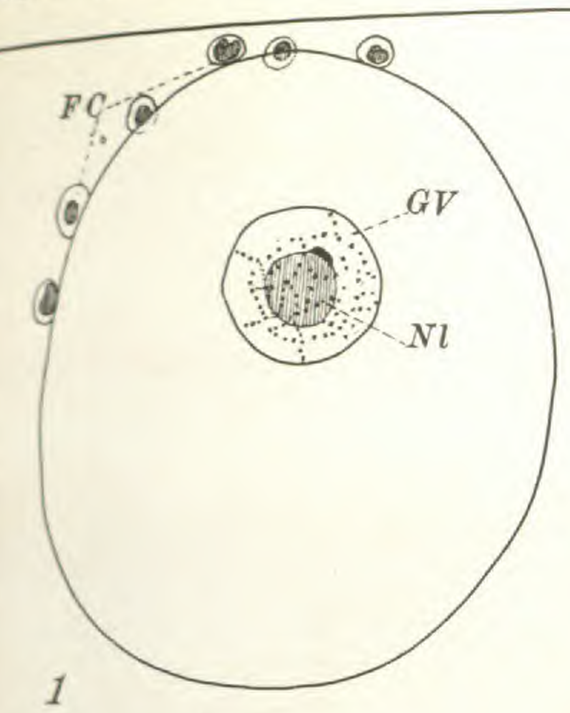
Figs. 12, 13. Eggs with large lobe opposite end of spindle, result of pressure. In fig. 12, the gonomeres are distinct; in fig. 13, the spindle has been pressed out of position and one of the nuclei lies in the cleavage plane and is constricted by it.

Fig. 14. Two-cell stage with gonomeres distinct.

Fig. 15. Two cells, interkinesis, with cell lobes in spindle axes of 2d cleavage.

Fig. 16. Two cells each with a tetraster.

Fig. 17. Four centrosomes, karyomeres, cleavage planes suppressed; the result, probably, of a tetraster.



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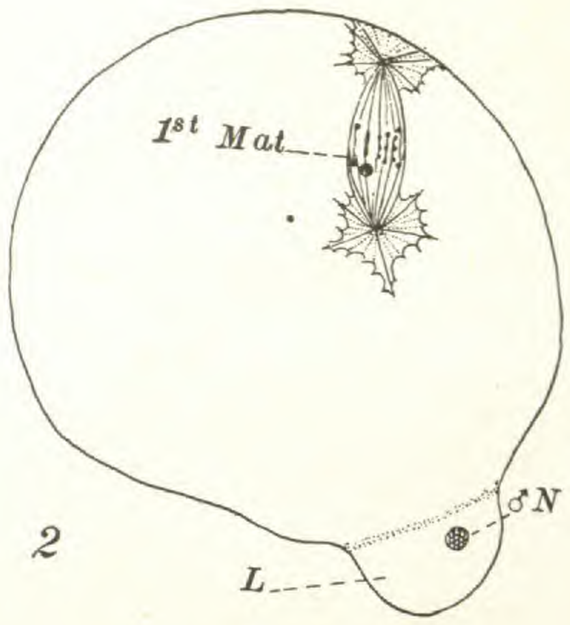

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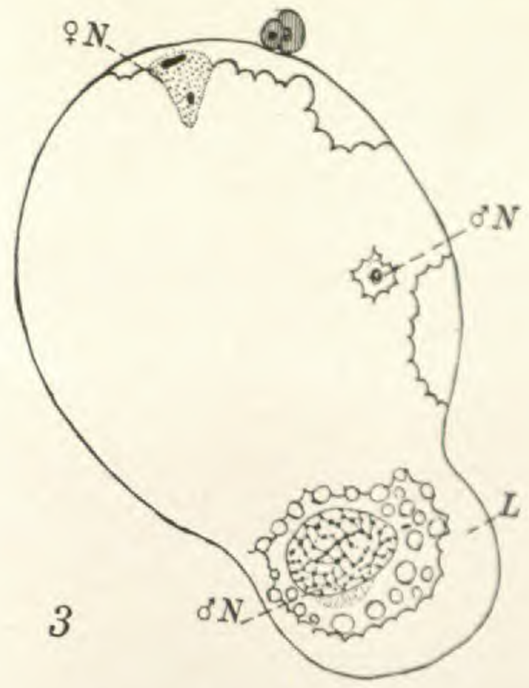

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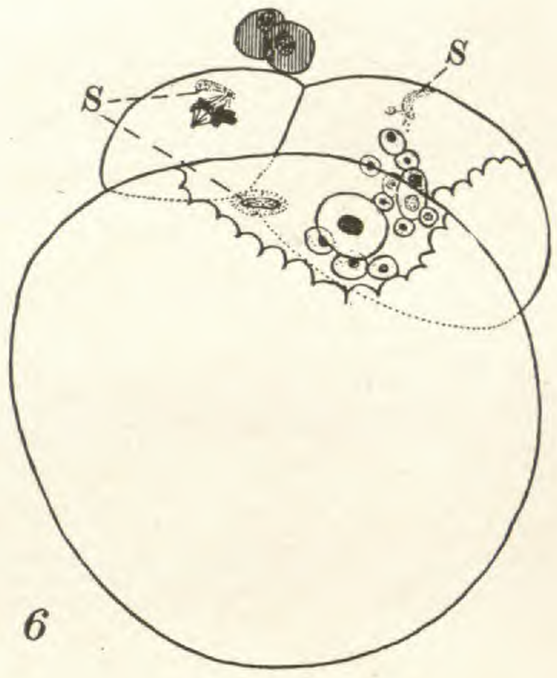

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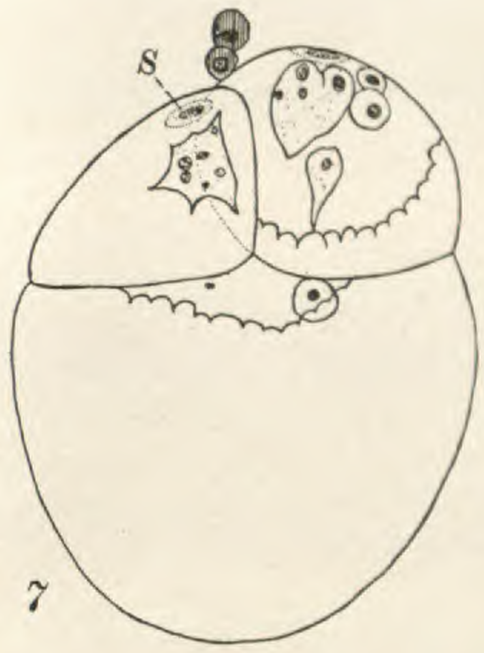

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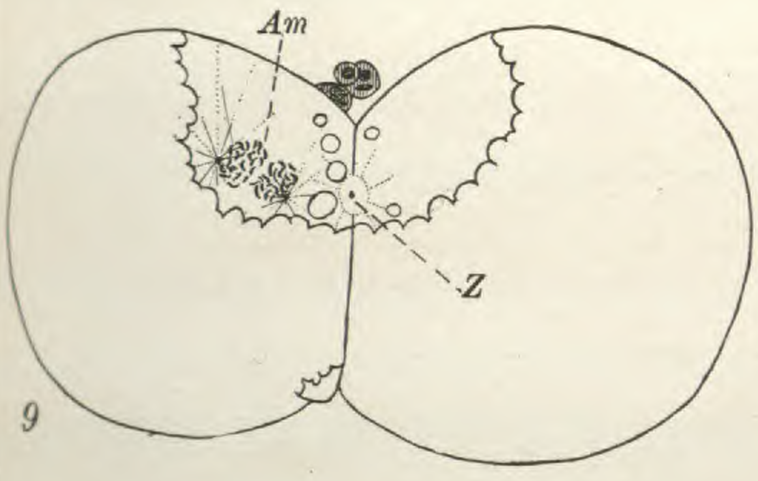

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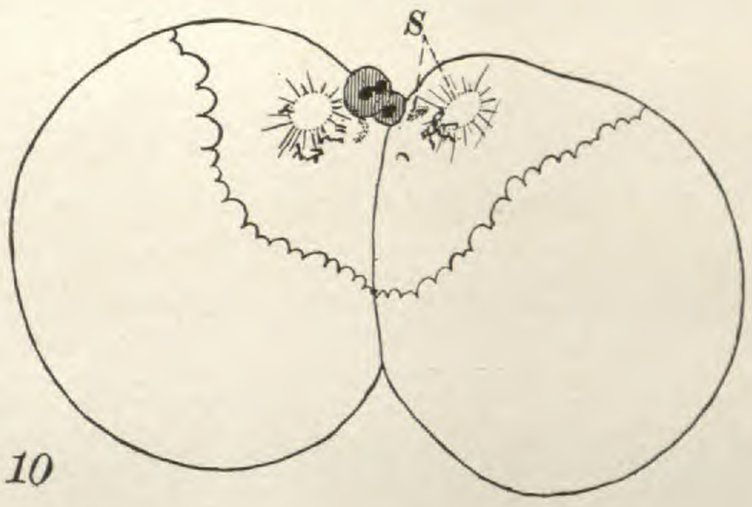

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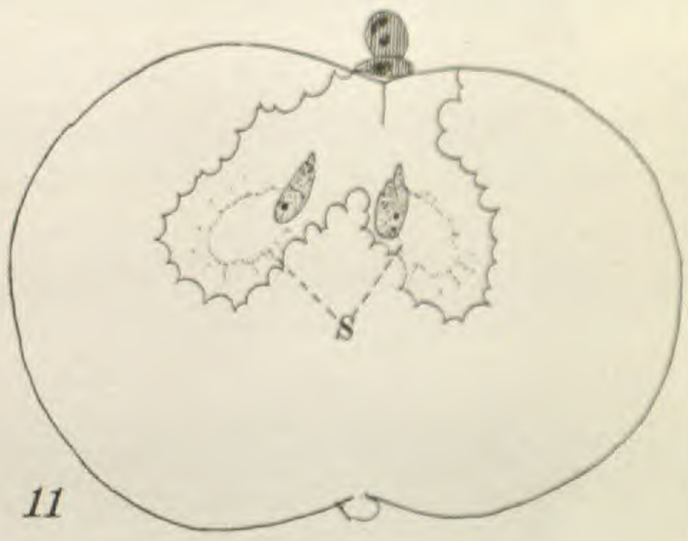

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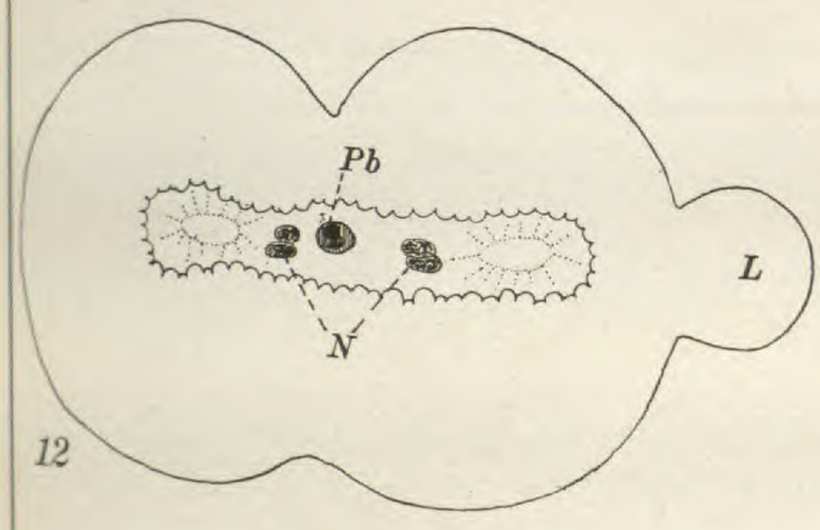

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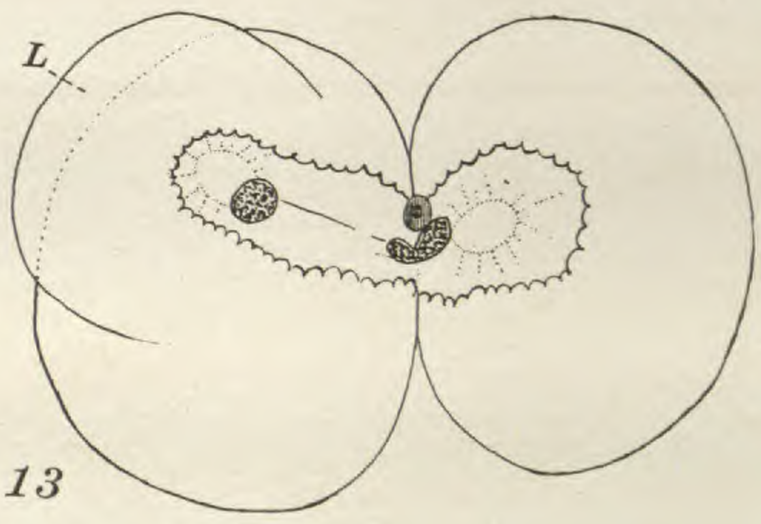

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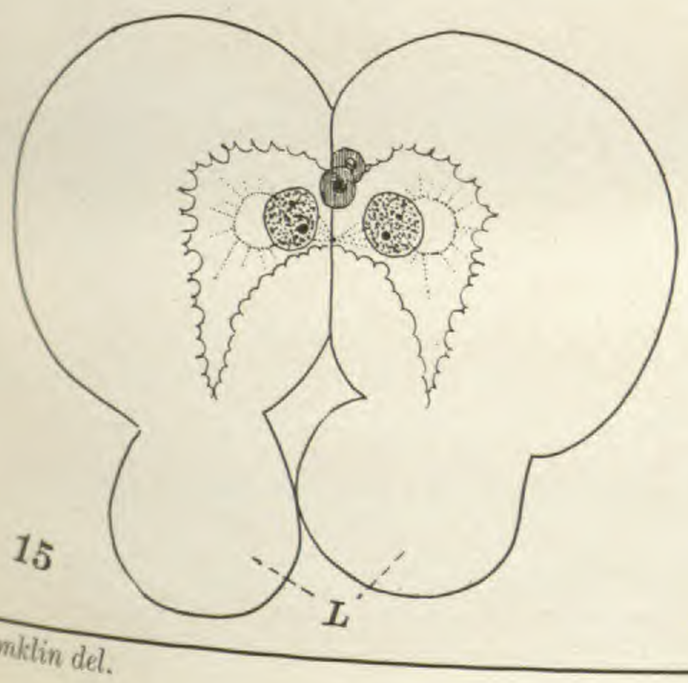

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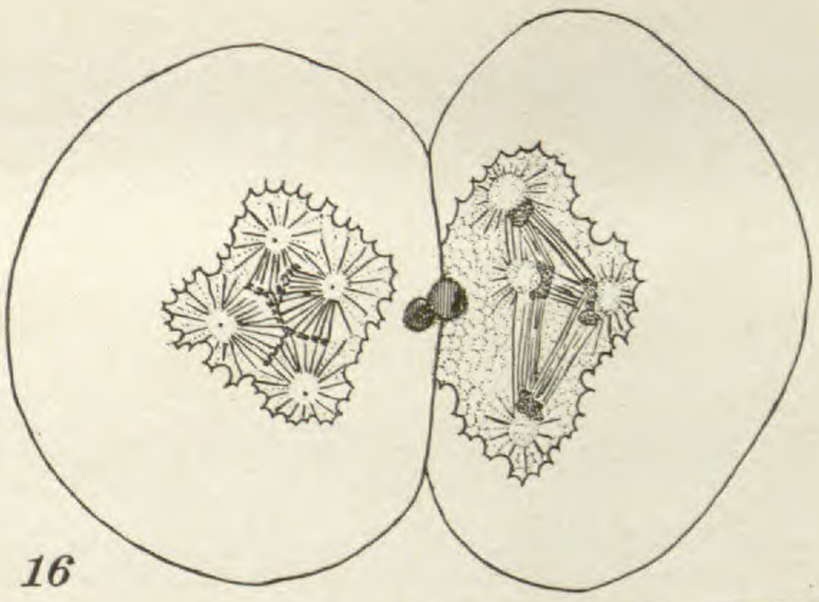

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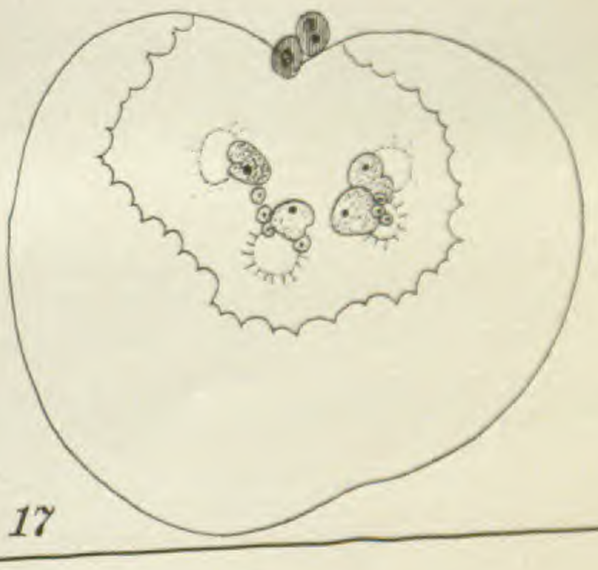

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Conklin del.

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

ABNORMALITIES FOUND IN NATURE

PLATE XLIV.

Abnormalities Found in Nature.

Figs. 18–26. Show effects probably of pressure; figs. 27–29, of dilute sea water.

Fig. 18. Four-cell stage; the nucleus is entirely lacking in two of the cells, though sphere and "Zwischenkörper" are present. The lobe attached to these cells indicates that the egg was subjected to pressure at the time of the 1st cleavage; since cells do not divide when nuclei are not present it is probable that the nuclei were lost after the 2d cleavage, though there is no indication as to the manner of their disappearance.

Fig. 19. Four-cell stage, showing in the lobes the effects of pressure during the 2d cleavage.

Fig. 20. Third cleavage showing a lobe in the spindle axis of one cell, the result of pressure.

Fig. 21. Third cleavage spindles are present, three in one cell, one in the other. In the latter the spindle axis (*Sp*4) is normal, in the former abnormal; spindle one (*Sp*1) lies at a higher level than spindles two and three (*Sp*2, *Sp*3).

Fig. 22. Five macromeres, the two upper ones normal, the three lower ones abnormal; due to a tetraster in the lower cells.

Fig. 23. Seven macromeres, six of them reaching to the animal pole where they have formed six micromeres of the first set. One of the macromeres ($1D^2$) lies far from the animal pole and does not form a micromere. The nuclei are double or irregular in shape in macromeres $1B$ and $1D'$ and also in the micromeres derived from them.

Fig. 24. Seven macromeres, six of them reaching to the animal pole where they have formed six micromeres of the first set and are forming in lacotropic direction six micromeres of the second set; one micromere $1D^2$ lies at a deep level and forms no micromere; a triaster is present in $1B$, a double nucleus in $1D^2$ and double nuclei and spheres are found in the micromeres $1b$ and $1d$.

Fig. 25. Six macromeres ($2A$–$2D$), five of which are dividing in dexotropic direction to give rise to five micromeres of the third set. There are six micromeres of the second set and twelve of the first with a central cell containing two nuclei unaccounted for. The micromeres of the first set have divided unequally as in normal eggs.

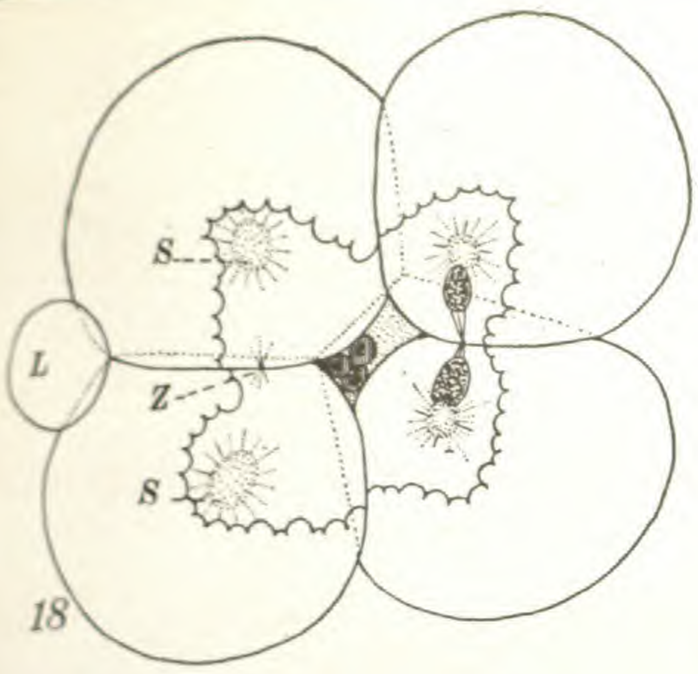
Fig. 26. Three macromeres, one of them (D) giving rise to a micromere of the first set in normal direction; the other ($3B$, $3C$) have produced micromeres of the first, second and third sets in normal manner.

Figs. 27–29. Three embryos of the same laying showing the failure of the micromeres to overgrow the macromeres, probably the result of dilution of sea water with fresh water.

Fig. 27. Shows a gastrula with ectomeres and mesomeres (M) forming a cap on the entomeres, though in normal eggs the former would have overgrown the latter at this stage.

Fig. 28. View of right side of embryo showing shell gland (*ShG*), posterior cell plate (*PCp*) and velum (V) but with endoderm (*End*) protruding through blastopore.

Fig. 29. Embryo similar to the preceding but viewed from anterior pole.



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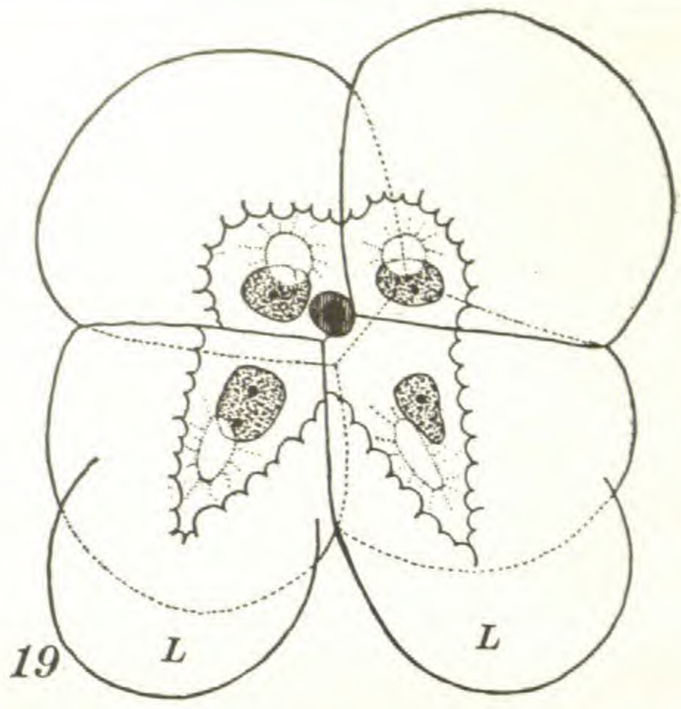

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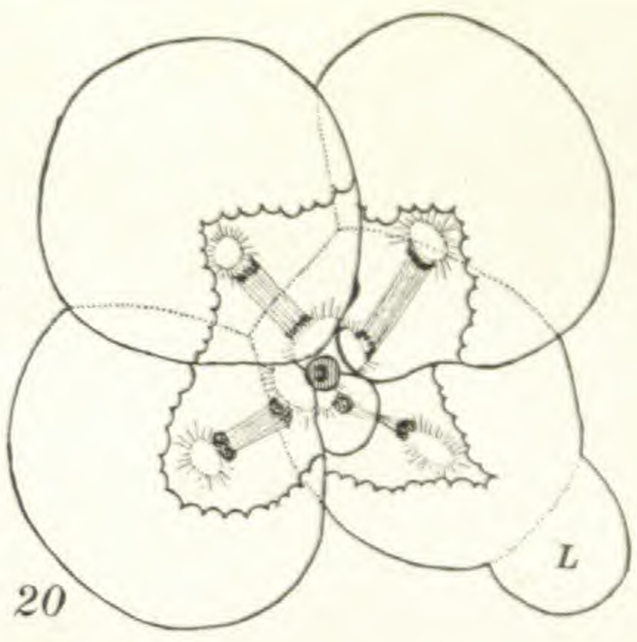

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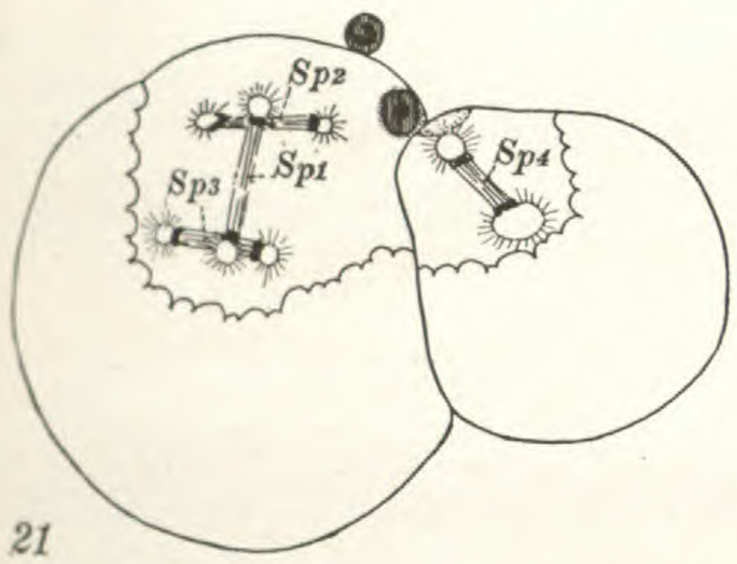

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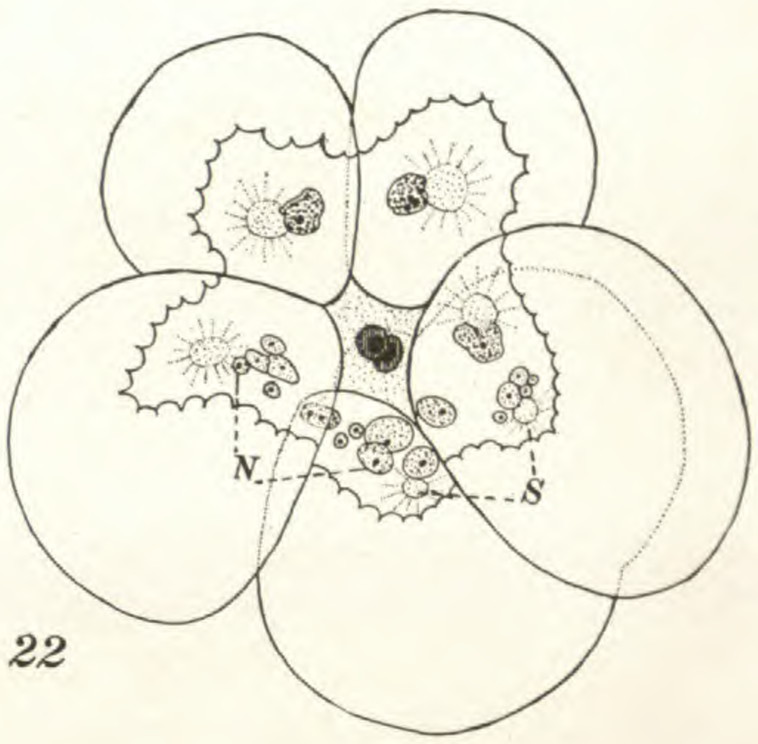

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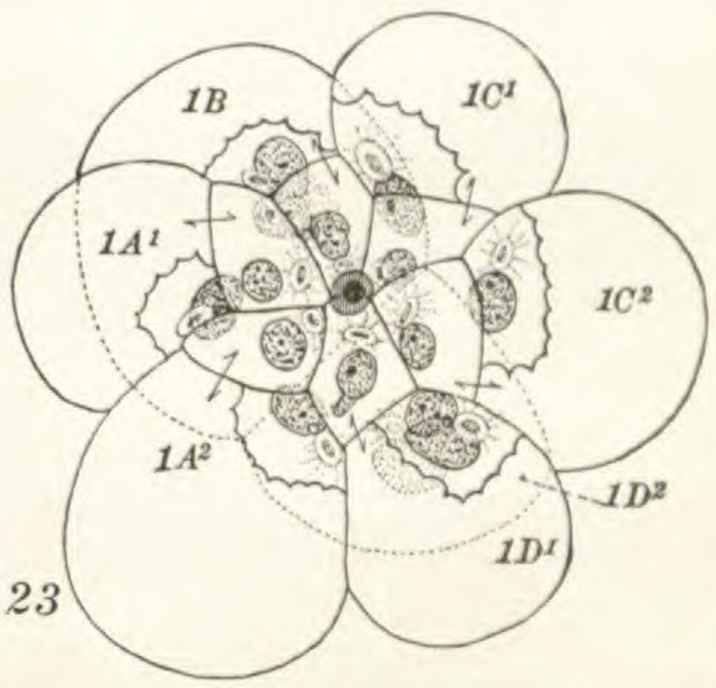

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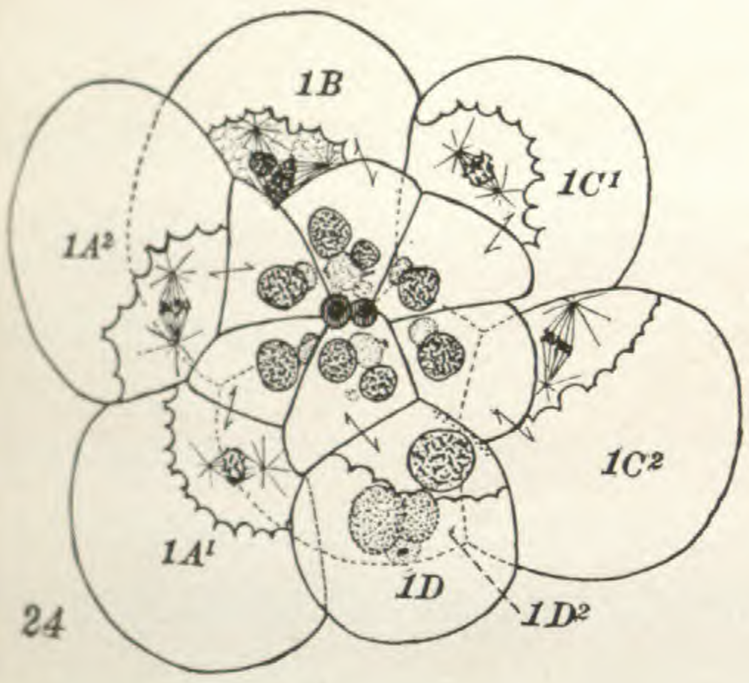

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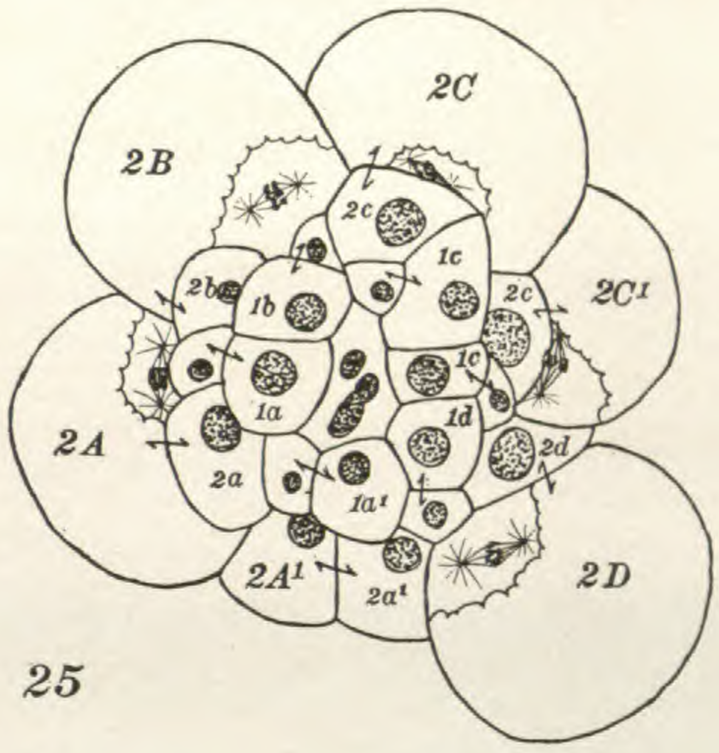

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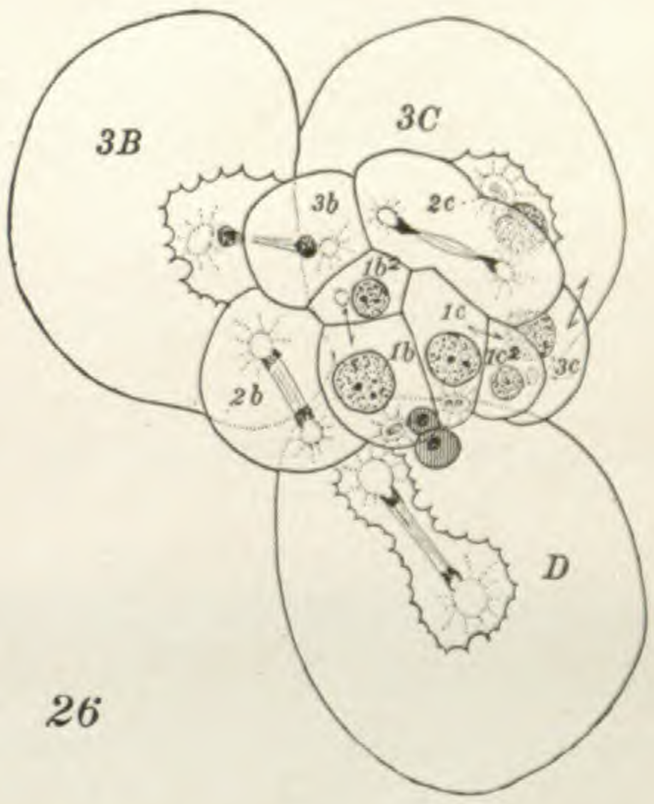

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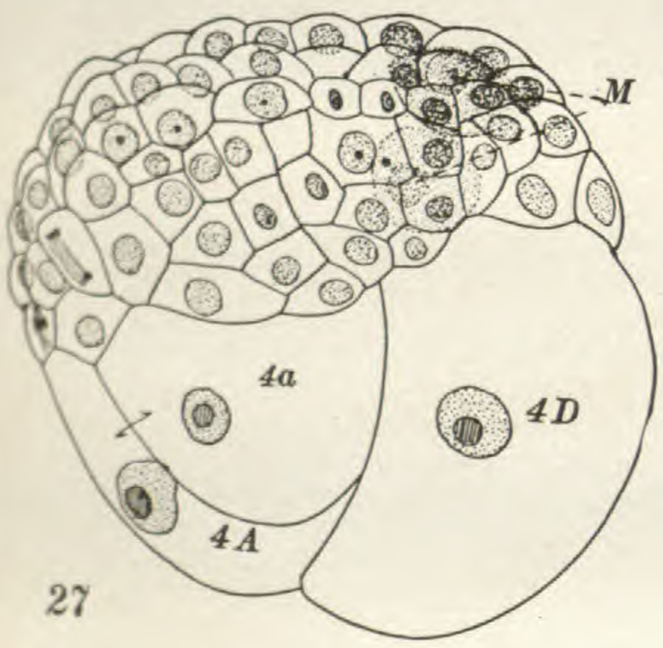

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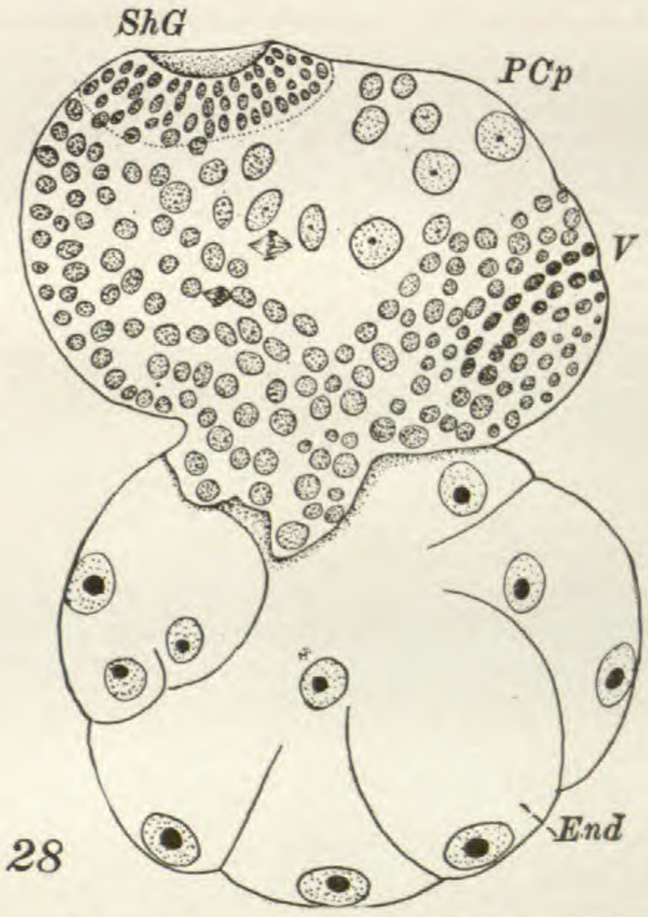

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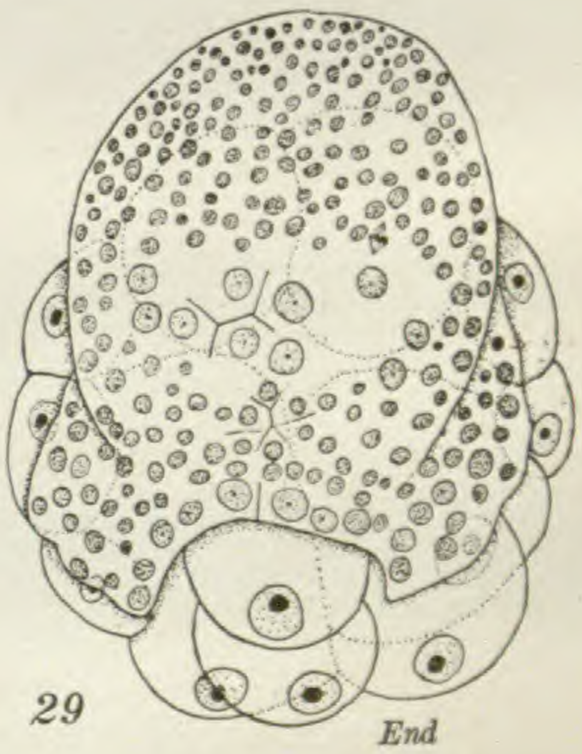

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Conklin del.

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

ABNORMALITIES FOUND IN NATURE

PLATE XLV.

Cleavage of Isolated Blastomeres.

Fig. 30. Exp. 906: Third cleavage in $\frac{1}{2}$ or $\frac{2}{4}$ blastomeres, separated by pressure; the cells are smaller than the normal macromeres, owing probably to loss of yolk during pressure; each cell is dividing dexiotropically as it should in the third cleavage, but the relative positions of spindles and cytoplasmic areas in the two cells have undergone certain changes as may be seen by comparison with fig. 20.

Fig. 31. Exp. 921: $\frac{1}{2}$ or $\frac{2}{4}$ blastomeres, separated by shaking; the spindles are normal in position though division in *B* has been delayed.

Fig. 32. Exp. 855: $\frac{1}{4}$ blastomere, isolated by shaking; the first micromere has been formed and the second is forming in typical manner. Original animal pole indicated by polar bodies.

Fig. 33. Exp. 855: $\frac{1}{4}$ blastomere, isolated by shaking; the first and second micromeres have formed in normal manner, and the former is dividing as in a whole egg. Original animal pole indicated by polar body.

Fig. 34. No. 714: $\frac{2}{4}$ blastomeres, probably separated by pressure; each macromere has given off a micromere in dexiotropic direction, as in whole eggs.

Fig. 35. Exp. 855: $\frac{1}{2}$ or $\frac{2}{4}$ blastomeres, separated by shaking; each has produced a first micromere in dexiotropic and a second in læotropic direction, and the former are dividing in læotropic direction just as in whole eggs. The micromere plate is a continuous one, without breaks.

Fig. 36. No. 711: $\frac{3}{4}$ blastomeres, one macromere having been separated, probably by pressure. Each macromere has formed one micromere in normal fashion, but a gap exists between micromeres 1*c* and 1*a*.

Fig. 37. Exp. 864: $\frac{1}{2}$ or $\frac{2}{4}$ blastomeres, separated by hypertonic sea water and then left in normal sea water 10 hrs. Each macromere has formed three micromeres, and the first and second of these have subdivided in normal fashion. The egg is a whole in the sense only that it shows no gaps where cells are missing.

Fig. 38. No. 715: $\frac{1}{4}$ egg, probably separated by pressure after third cleavage, as shown by the fact that two micromeres of the first set (1*a* and 1*b*) are present.

Fig. 39. Exp. 875: $\frac{3}{4}$ blastomeres, macromere *C* having been destroyed in dilute sea water; the macromeres have given off the first micromeres, and these have subdivided in typical fashion, forming a triangular, but continuous micromere plate.

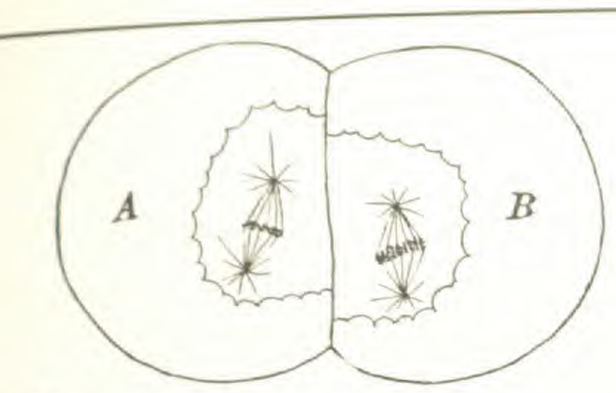
Fig. 40. Exp. 958: $\frac{3}{4}$ blastomeres, separated by shaking. Cells *A* and *D* have given rise to first and second micromeres in normal manner; *B* has formed only the first micromere and both 1*B* and 1*b* lack nuclei.

Fig. 41. Exp. 867: $\frac{3}{4}$ blastomeres, separated in hypertonic sea water. Typical cleavage of micromeres and macromeres of each quadrant represented, but the cells of one quadrant are wholly lacking.

Fig. 42. Exp. 1002 (2): $\frac{3}{4}$ blastomeres, separated by pressure. Cleavage typical for each quadrant, but delayed in quadrant *B*; the third micromere is just coming off from 2*D*.

Fig. 43. Exp. 958: $\frac{3}{4}$ blastomeres, separated by shaking. The cleavage of these three quadrants *A*, *C*, and *D* is absolutely typical; the cells of the fourth quadrant (*C*) are entirely lacking, but there are no gaps to mark the places from which they have dropped out. Each macromere has produced three micromeres, and in addition *D* has given rise to a fourth, the mesentoblast, $4d(= M^1, M^2)$. The micromeres have each divided in typical manner, giving rise to a cross (stippled cells) with three arms instead of four.

Fig. 44. Exp. 959: $\frac{3}{4}$ blastomeres separated by shaking; the cleavage of each macromere and the subdivisions of each micromere have taken place as in normal eggs.



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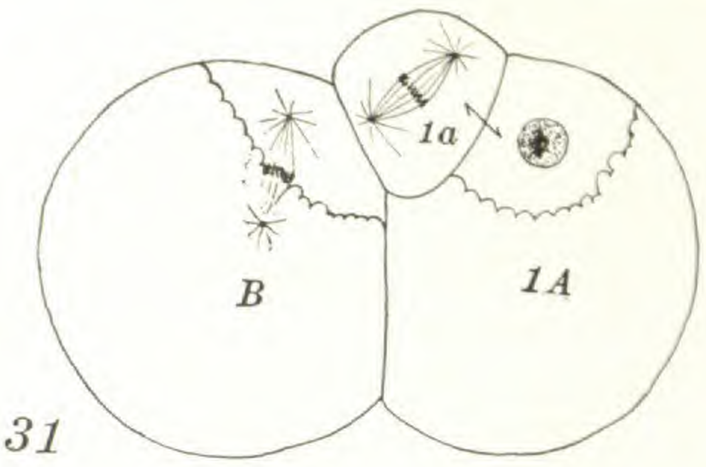

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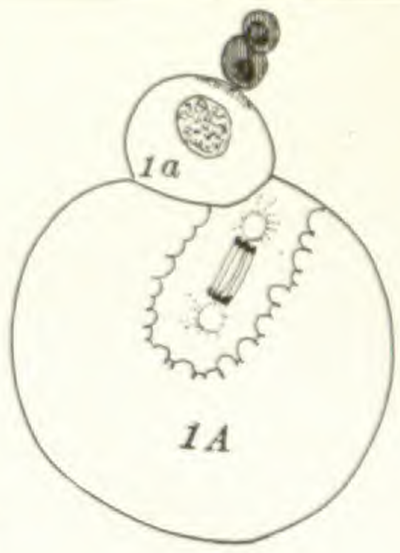

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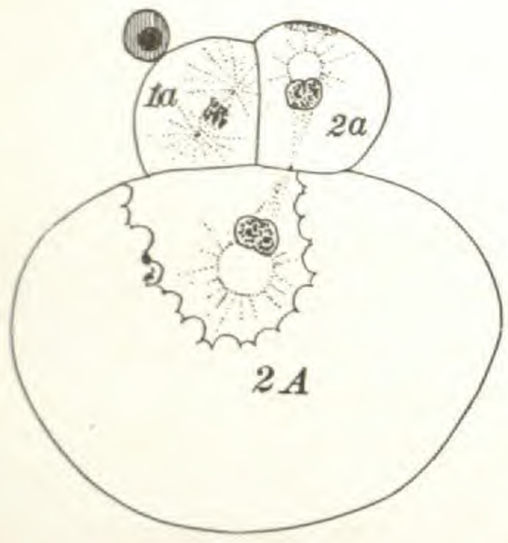

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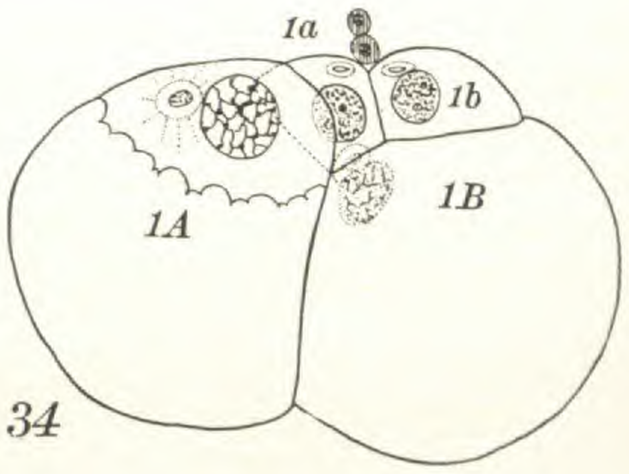

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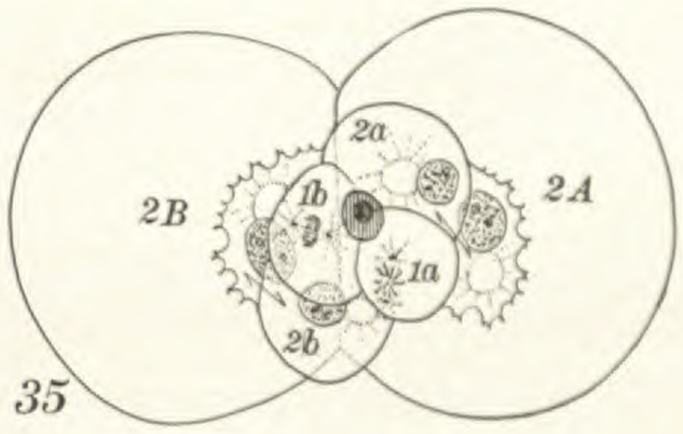

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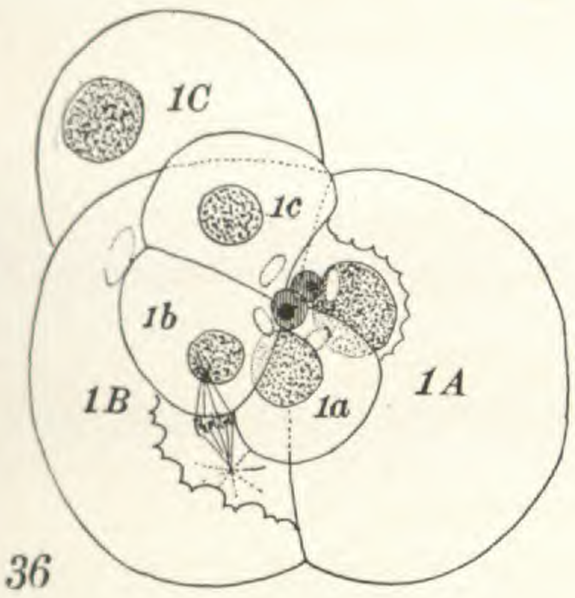

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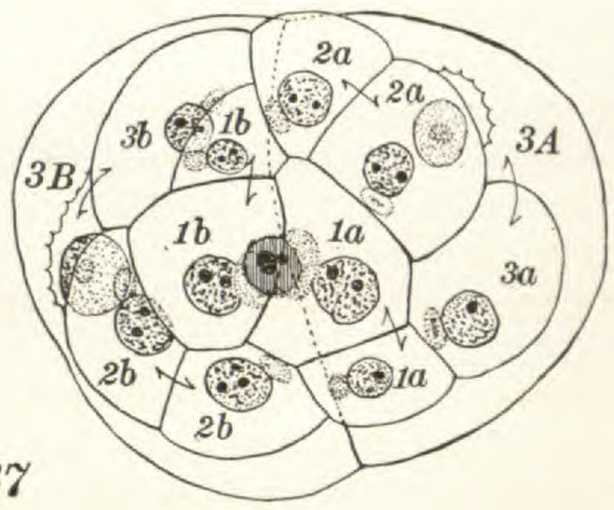

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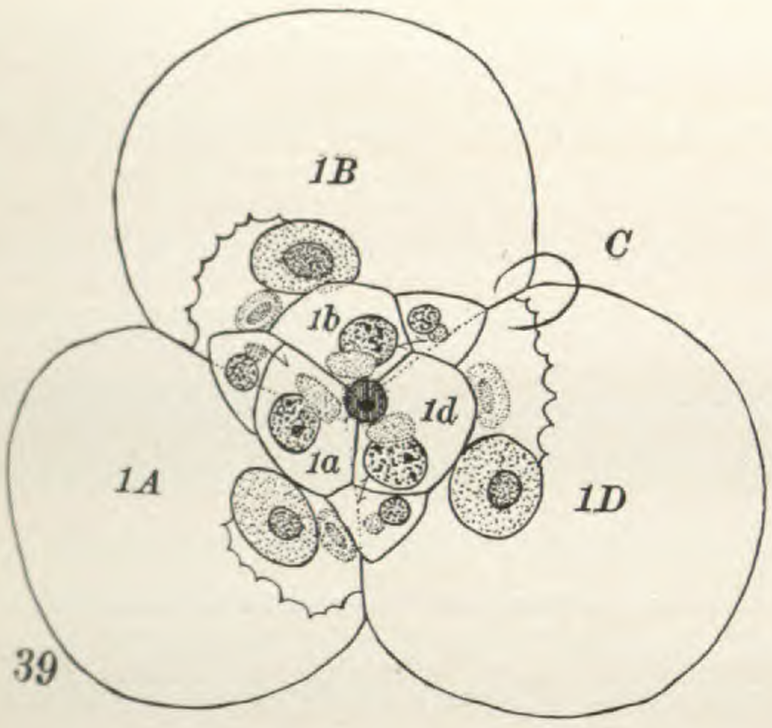

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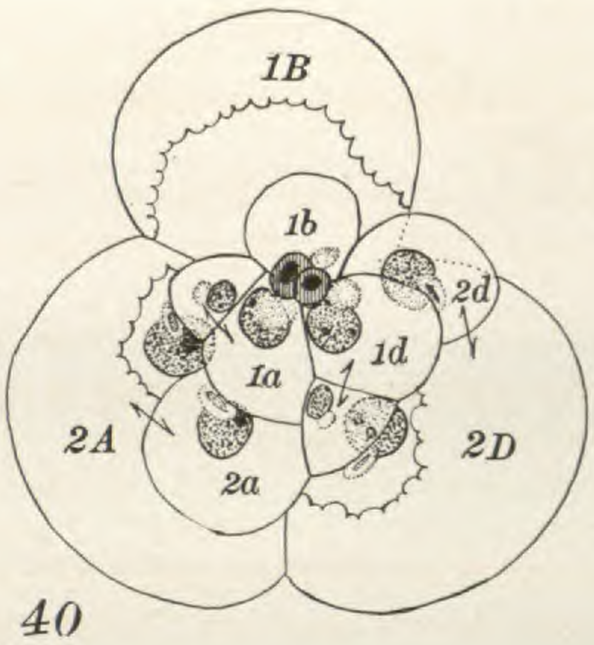

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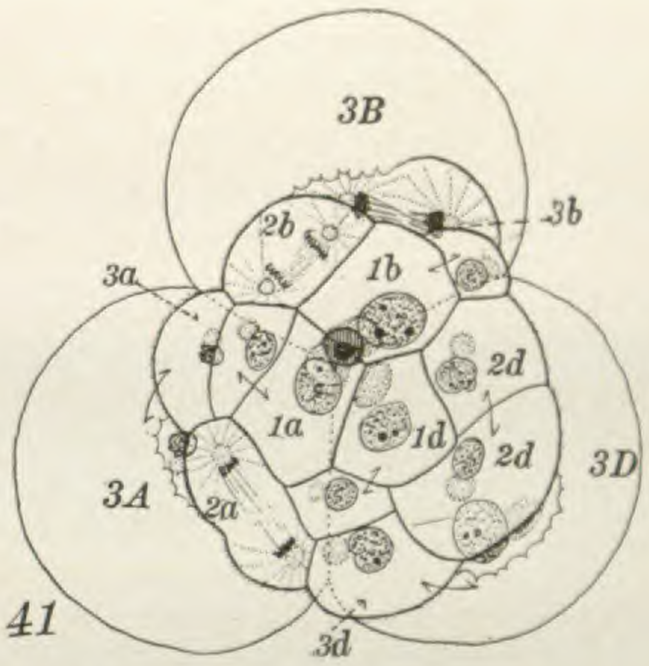

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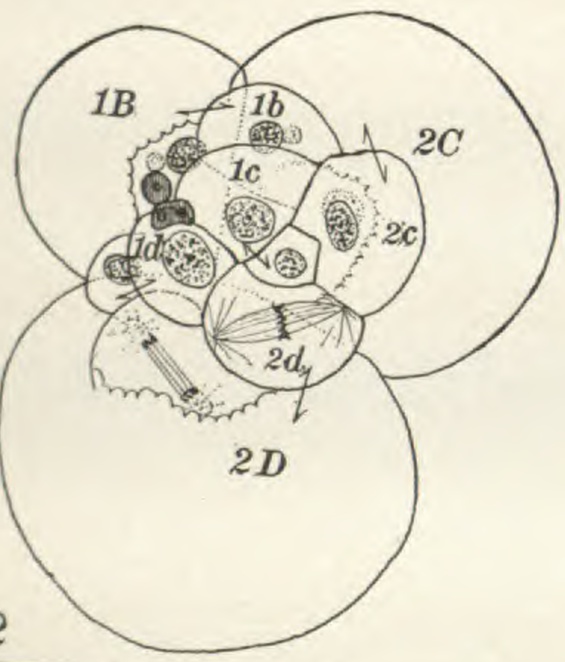

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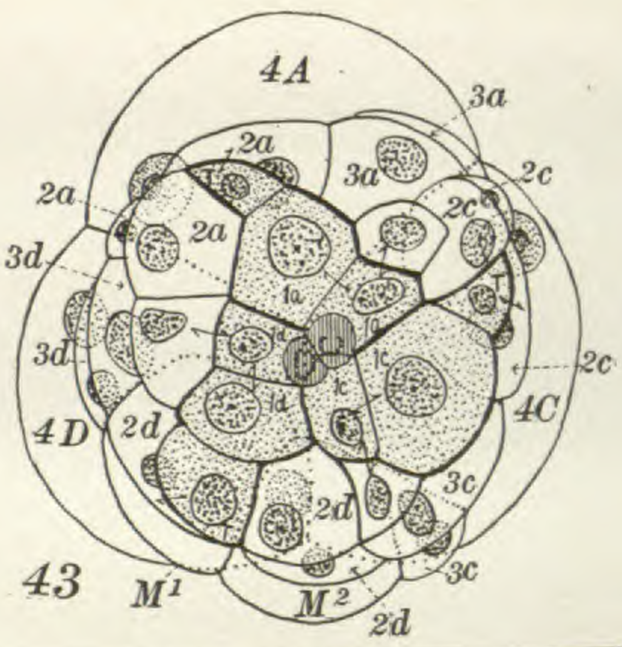

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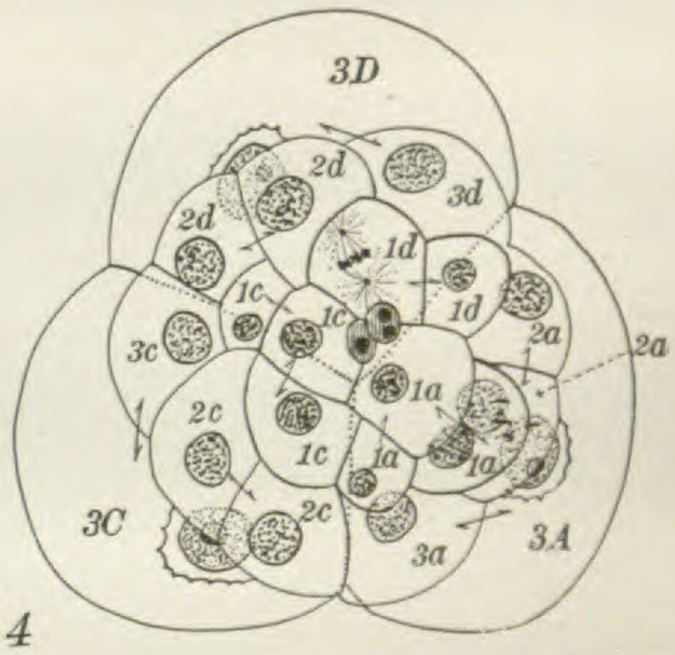

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Conklin del.

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

CLEAVAGE OF ISOLATED BLASTOMERES

PLATE XLVI.

Effects of Pressure.

Fig. 45. Exp. 918: Egg pressed during formation of second polar body, which is abnormally large.

Fig. 46. Exp. 918: Egg pressed during first cleavage which was rendered unequal; nuclei abnormally lobulated.

Fig. 47. Exp. 958: Egg shaken during first cleavage. Similar to preceding.

Fig. 48. Exp. 901: Very large yolk lobe at vegetal pole of one of the cells.

Fig. 49. No. 724: Egg probably pressed during the first cleavage; second cleavage spindles abnormally small.

Fig. 50. Exp. 918: Pressed during second cleavage in the direction of the spindle axes; macromeres *A* and *B* have divided normally giving rise to micromeres 1*a* and 1*b*; in macromere *CD* the second cleavage is still incomplete, and the entire amphiaster is abnormally large.

Fig. 51. Exp. 911: Pressed during the first cleavage; three macromeres with multiple nuclei formed probably as result of a triaster.

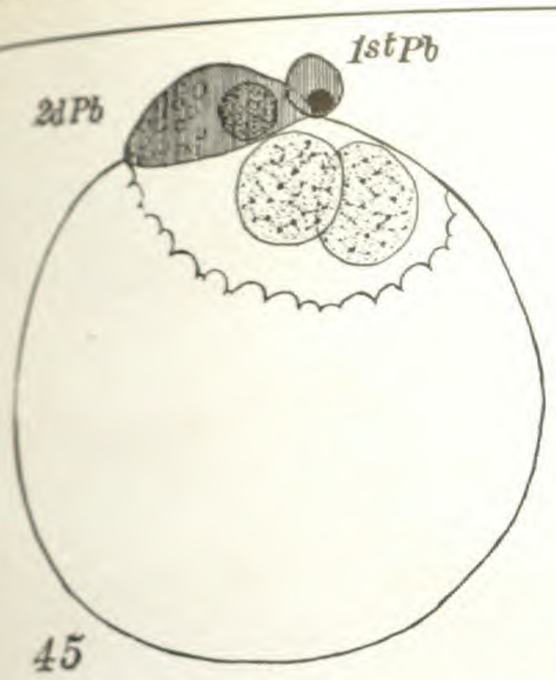
Fig. 52. Exp. 911: Pressed during second and third cleavages in chief axis of egg; macromeres *C* and *D* with their micromeres approximately normal; macromeres *A* and *B* have divided in abnormal planes giving rise to macromeres $1A^1$ and $1B^1$ instead of micromeres.

Fig. 53. Exp. 911: Pressed during second and third cleavages in chief axis of egg; all the upper tier of cells except 1*c* are abnormally large and are dividing like micromeres of the first set; in $1B^2$, 1*C* and $1D^2$ the direction of division is like that in the formation of the 2d set of micromeres.

Fig. 54. Exp. 915: Pressed during 2d and 3d cleavages in chief axis of egg; macromere *A* divided nearly equally into $1A^1$ and $1A^2$, which are now forming micromeres of the 1st set; macromeres 1*B*, 1*C* and 1*D* are forming micromeres of the second set.

Fig. 55. Exp. 904: Pressed during 3d cleavage, the direction of which was changed from dexiotropic to læotropic in all quadrants except *B*; correspondingly the next cleavage (shown by spindles) is dexiotropic, instead of læotropic as in typical eggs.

Fig. 56. Exp. 915: Pressed in chief axis during the 4th cleavage, the chief result being the enlarged size of 2*a* and 2*c*.



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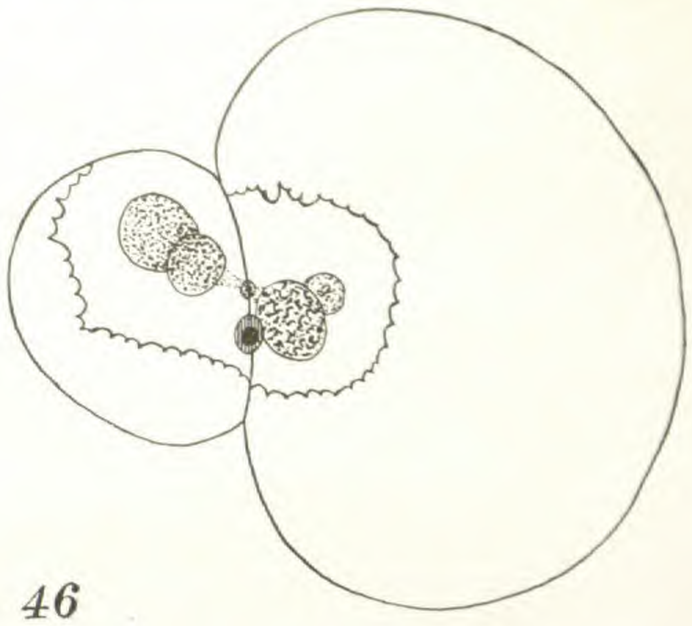

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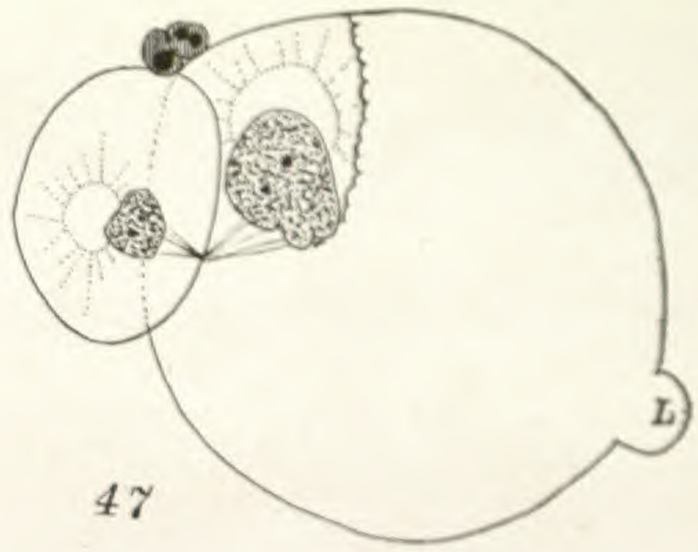

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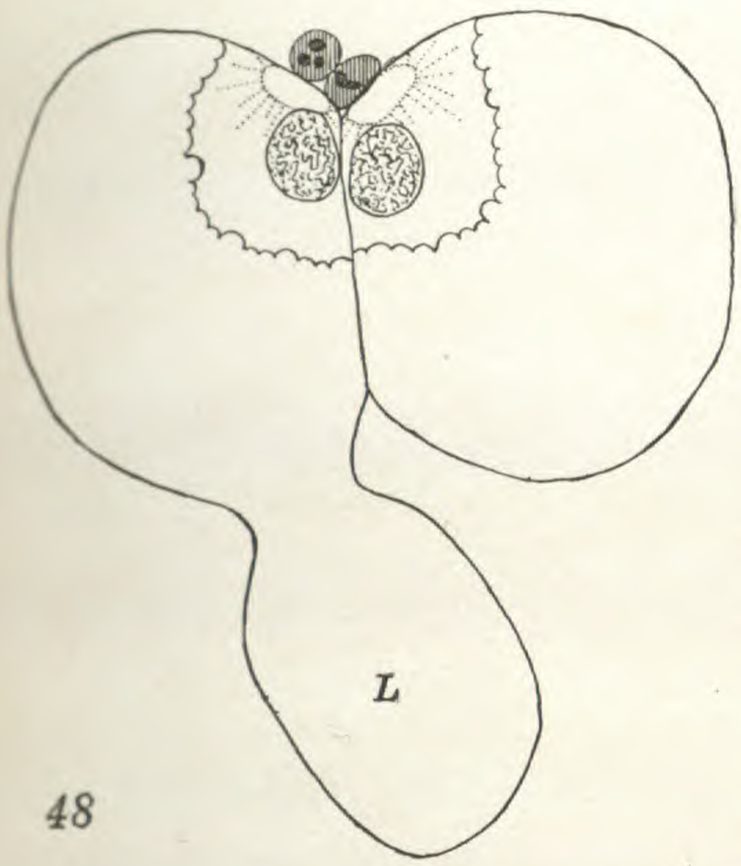

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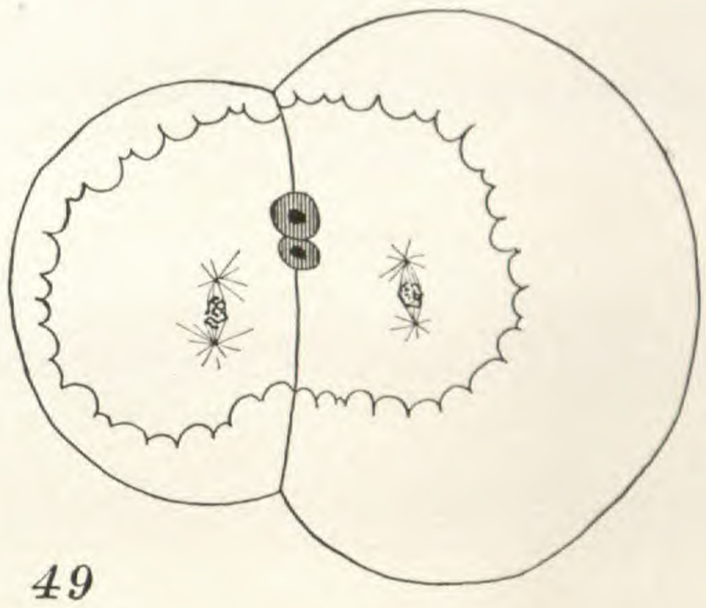

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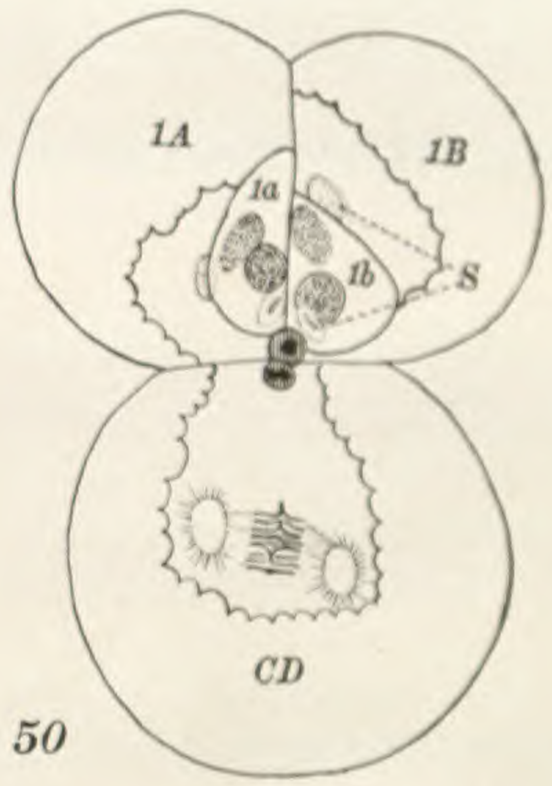

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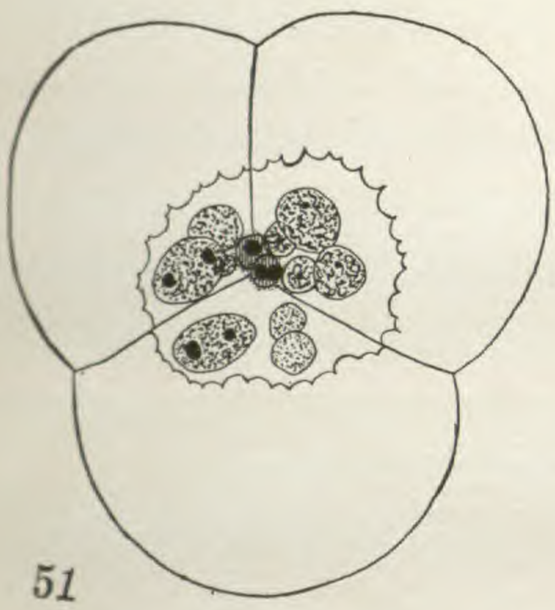

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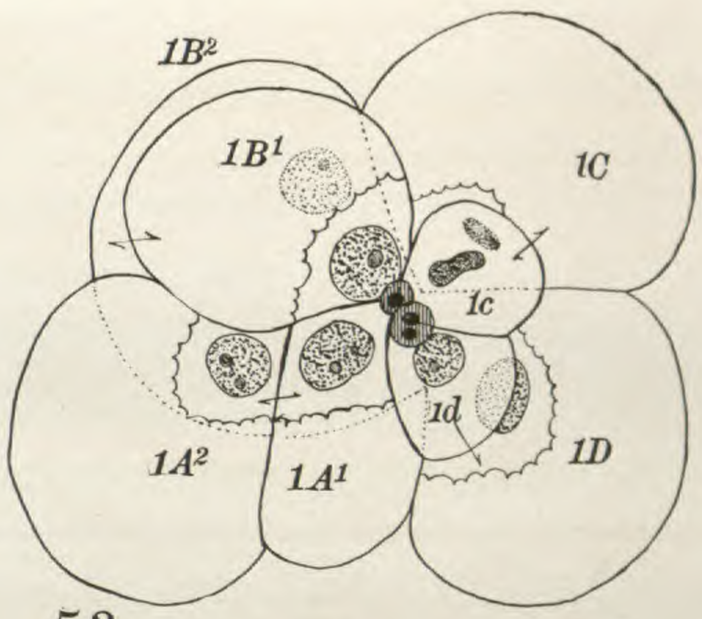

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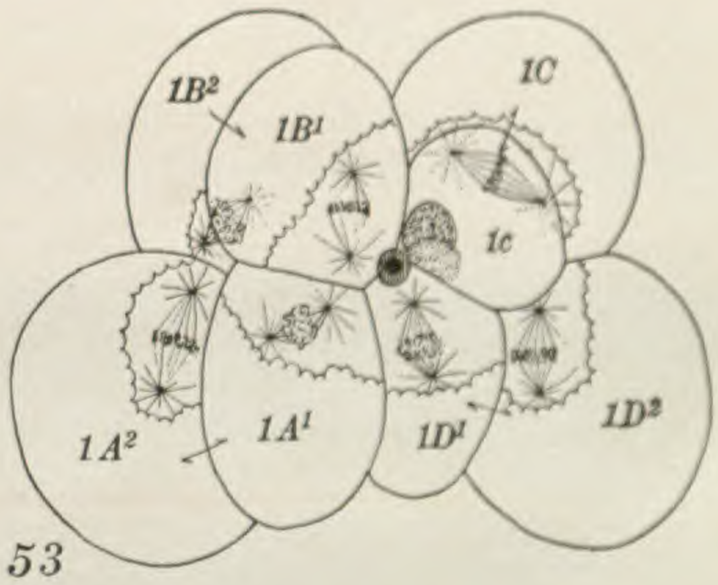

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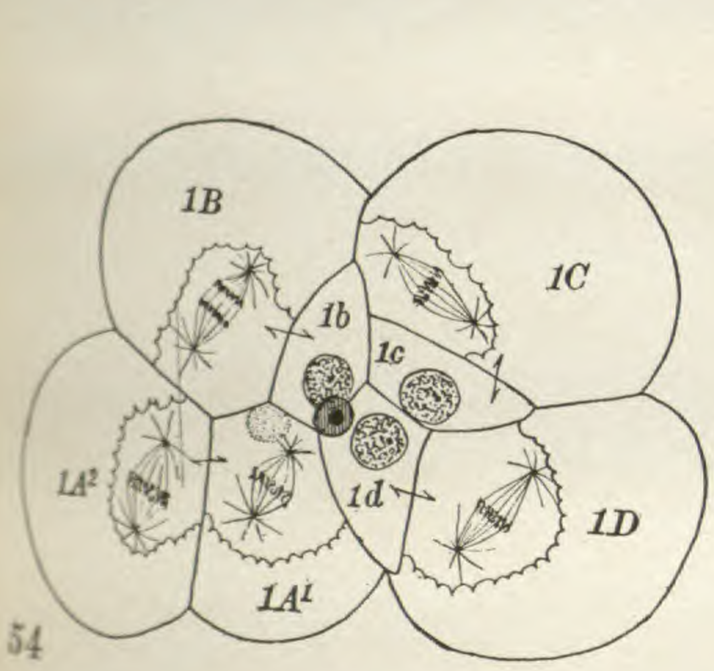

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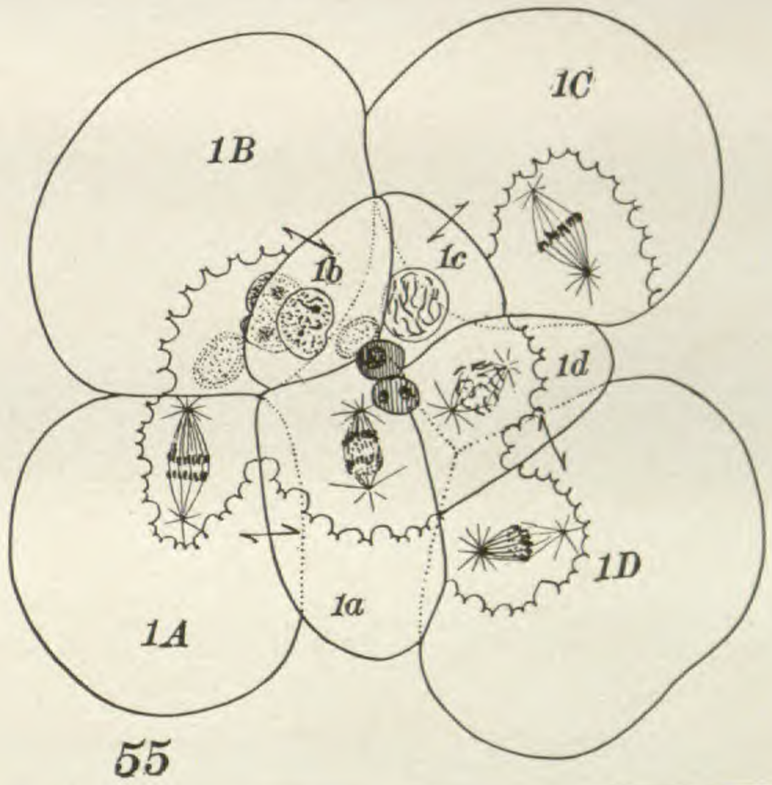

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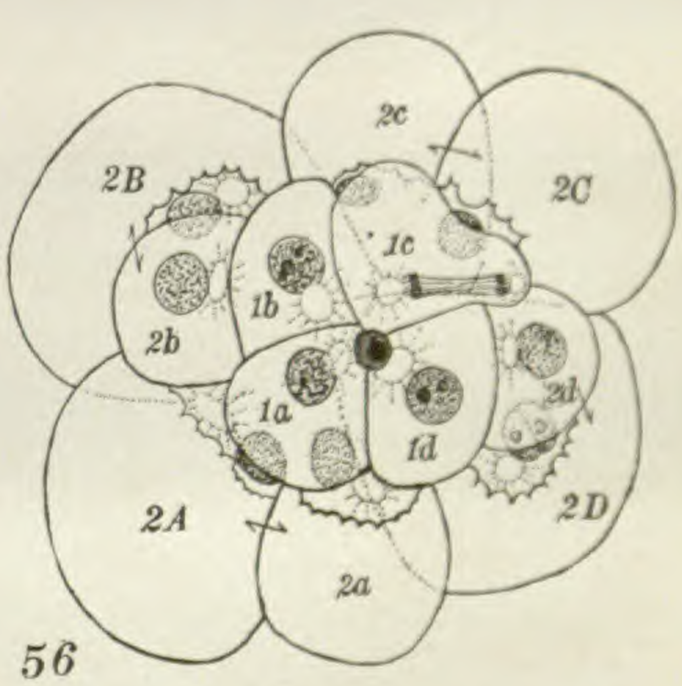


56

PLATE XLVII.

Effects of Pressure.

In all figures except 57, 65, 66 the axis of pressure was in the direction of the egg axis.

Fig. 57. Exp. 1003: Pressure parallel with the egg axis has produced a linear arrangement of the four macromeres, each of which preserves its original polarity and is dividing to form the first set of micromeres.

Fig. 58. Exp. 1003: Pressure in the chief axis of the egg has led to the formation of the micromeres of the 1st and 2d sets between the macromeres, instead of above them. The micromeres are larger than usual and the 1st set has subdivided giving off "turret" cells two of which ($1b^2$ and $1d^2$) are much larger than usual, while the other two ($1a^2$ and $1c^2$) have been forced to the lower side of the egg.

Fig. 59. Exp. 915: Pressure in the direction of the egg axis has led to the formation of eight macromeres, each of which is giving off in a dexiotropic direction a micromere of the 1st set.

Fig. 60. Exp. 915: Pressure in the egg axis during the 4th cleavage has caused the formation of larger micromeres than normal, especially in quadrants *C* and *D*, indeed the 2d division of *C* is nearly equal, giving rise to two macromeres; in the subdivisions of the 1st set of micromeres the "turret" cells ($1a^2$–$1d^2$) are much larger than usual.

Fig. 61. Exp. 915: In this case the pressure was probably applied after the formation of the 1st set of micromeres which are normal; the 2d set is also normal except in quadrant *A*, where the macromere 1*A* divided nearly equally into macromeres $2A^1$ and $2A^2$, and the former has divided into $2A^1$ and $2a^1$.

Fig. 62. Exp. 1001 (1): Normal except that macromere *C* divided equally at its fisrt division; the right upper half then gave off a micromere of the first set ($1c^1$) which, judging by the shape of the cell, is about to form a "turret" cell as in the other three quadrants.

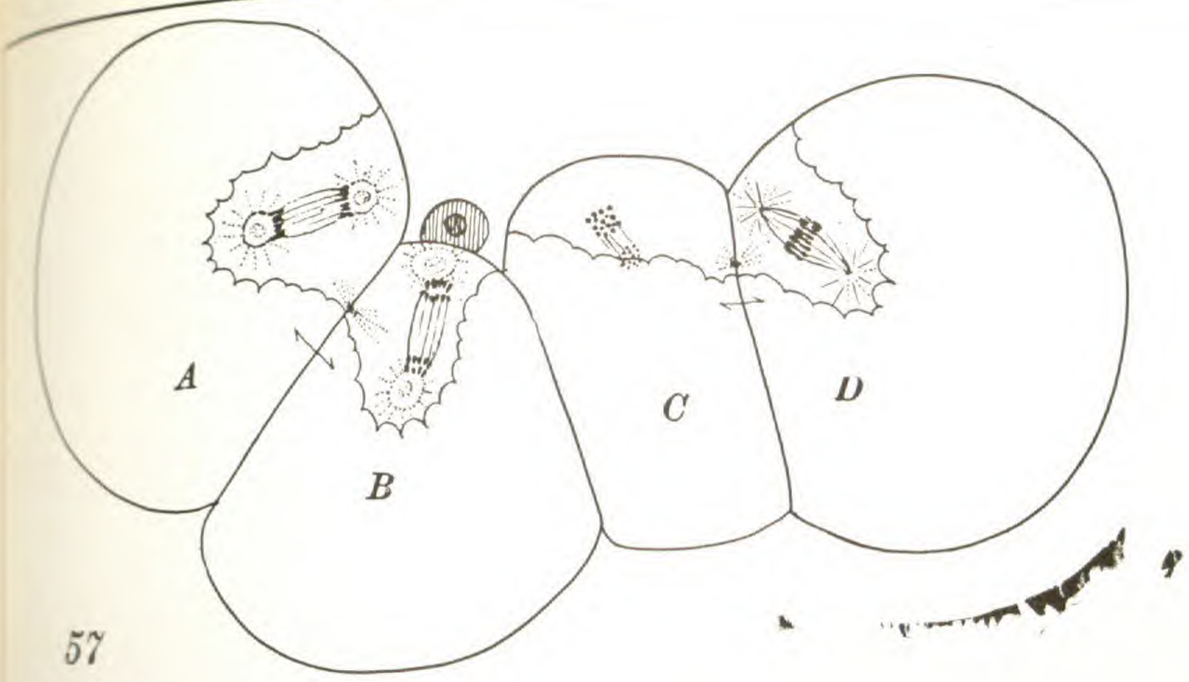
Fig. 63. Exp. 1004 (2): Pressed during the 3d cleavage, macromeres *A* and *D* divided nearly equally, thus increasing the number of macromeres to six, each of which has formed a micromere of the 1st set, while *C* has produced also a micromere of the 2d set (2*c*).

Fig. 64. Exp. 1003: Pressed during the formation of the 2d set of micromeres, which are much larger than usual; in the subdivision of 1*b* and 1*c* the peripheral products ("turret" cells) have been forced to the lower pole of the egg, and the macromeres have been pushed apart as in fig. 58.

Fig. 65. Exp. 915: Compressed obliquely to the egg axis; macromere *B* being shoved under the micromere plate; macromere *A* formed a first micromere larger than normal, which has divided equally ($1a^1$, $1a^2$), and then gave rise to a second "micromere," which is really a macromere ($2A^1$).

Fig. 66. Exp. 1001 (1): Compressed parallel with the egg axis, *B* and *D* being shoved under the other cells; the 1st and 2d sets of micromeres are nearly normal; at its 2d division *A* divided nearly equally into 3*A* and $3A^1$, each of which has formed a micromere (2*a*, 2*a*) in a dexiotropic direction.

Fig. 67. Exp. 1001 (3): The cleavage is normal except that 4*d* is larger than usual, the result of pressure in the direction of the egg axis; the cells of the ectodermal cross are stippled.



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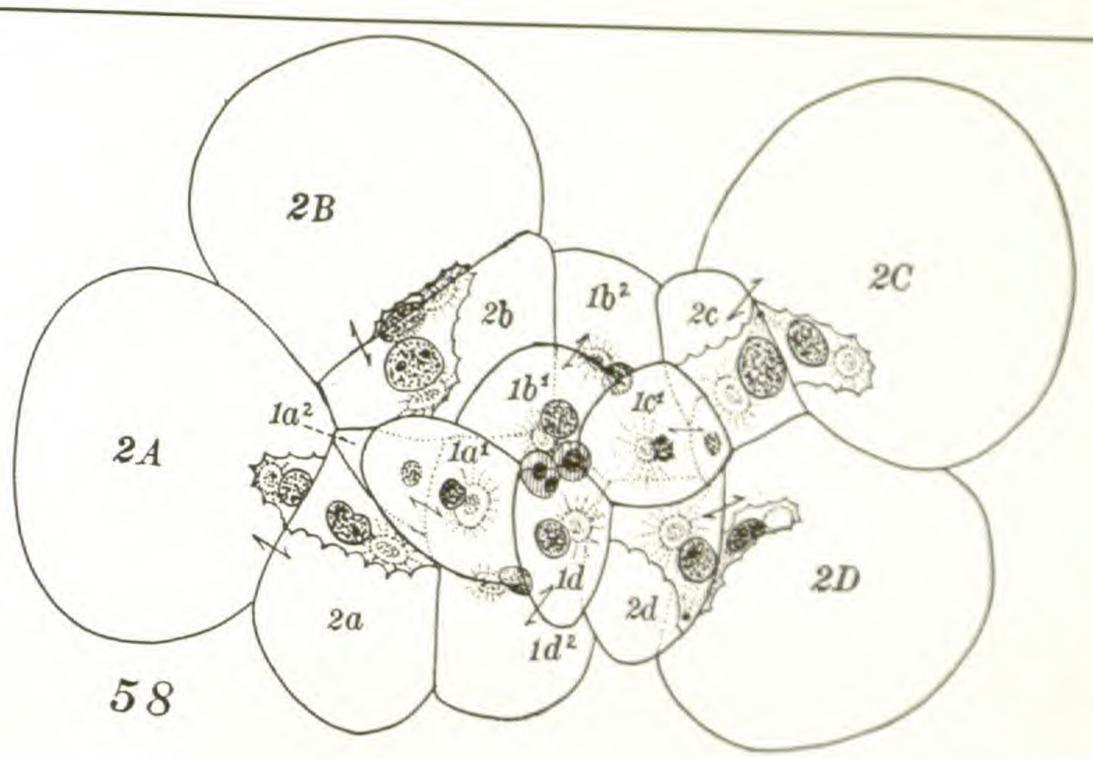

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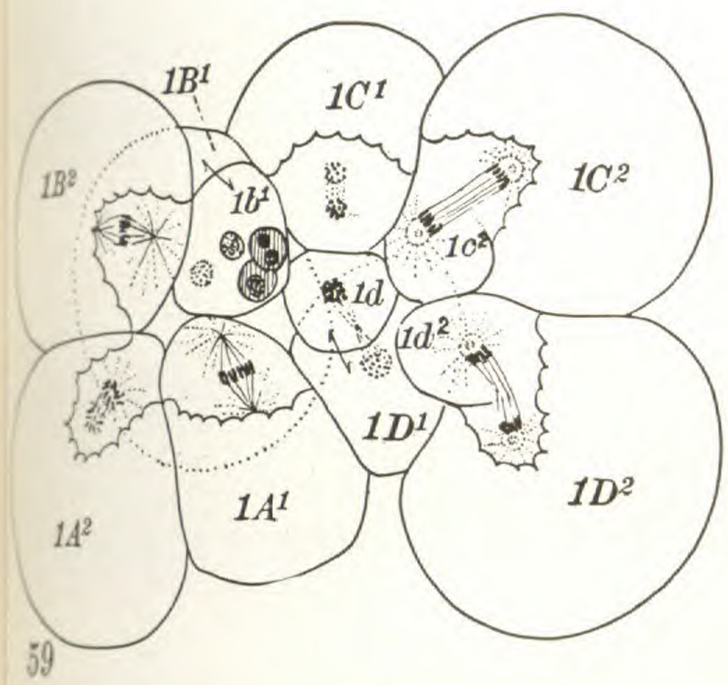

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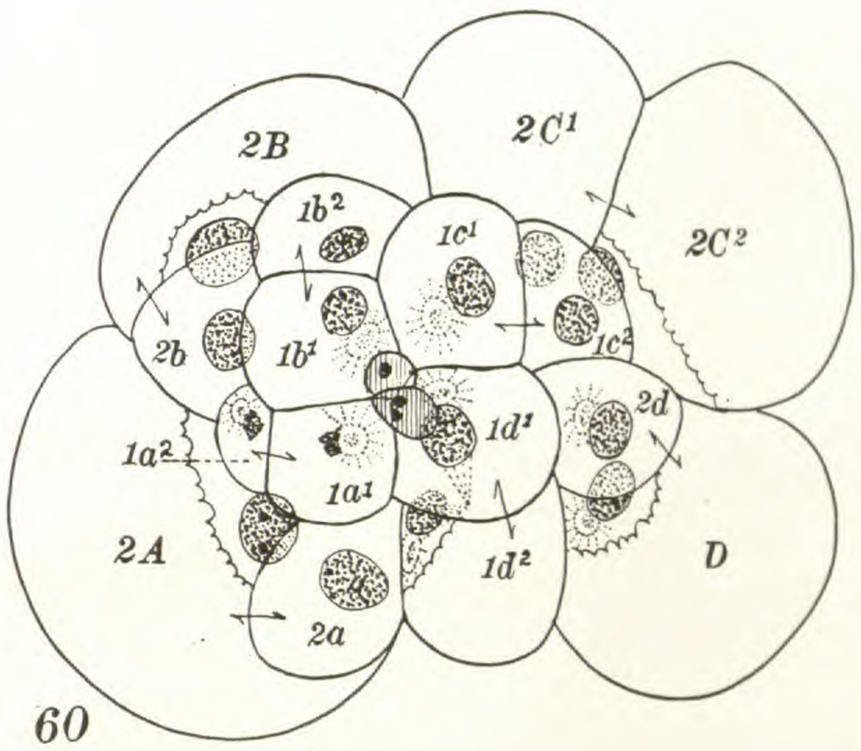

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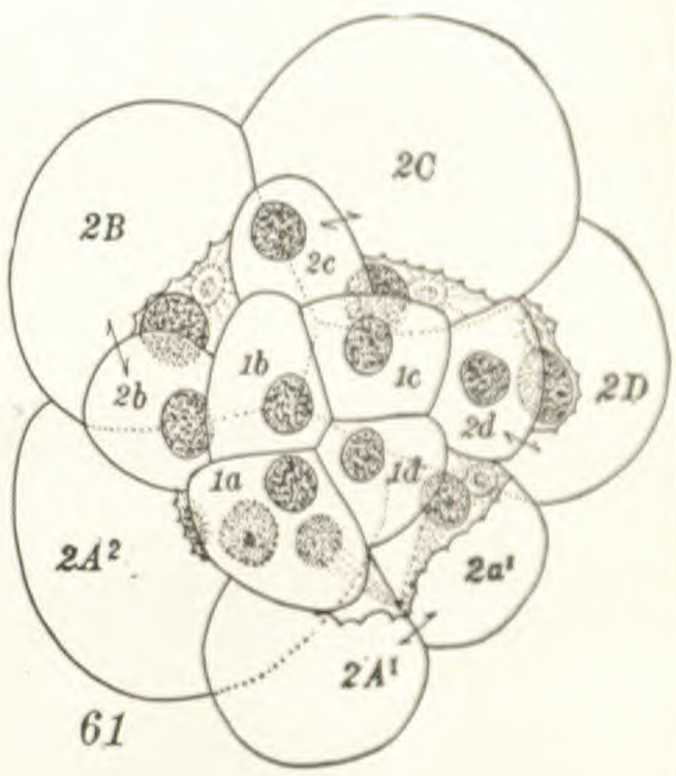

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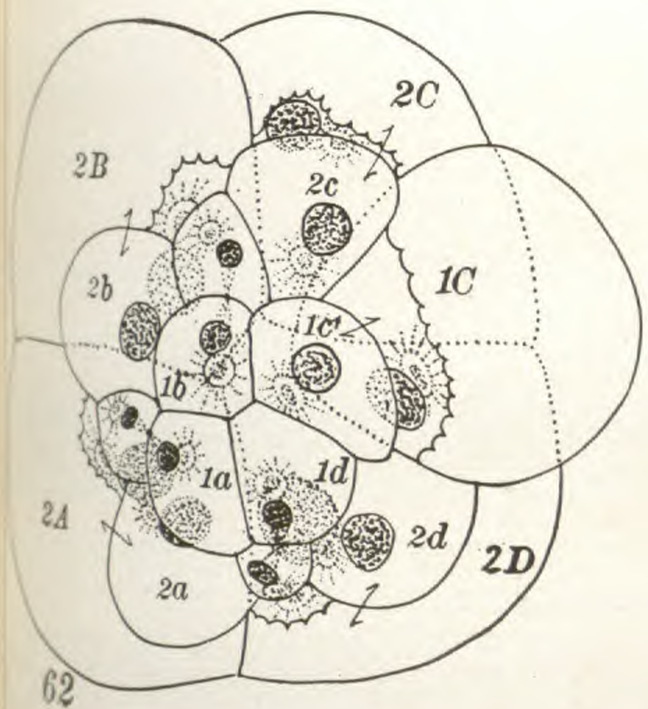

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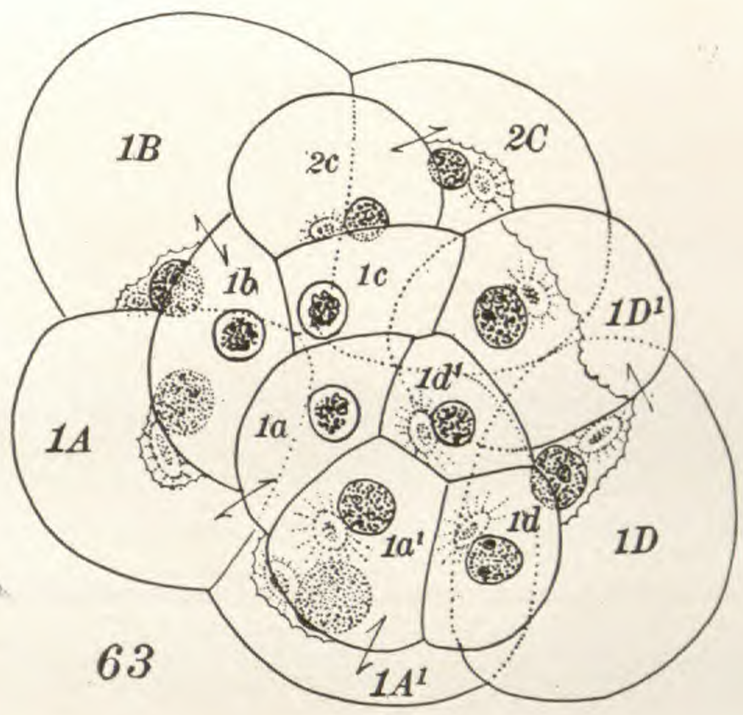

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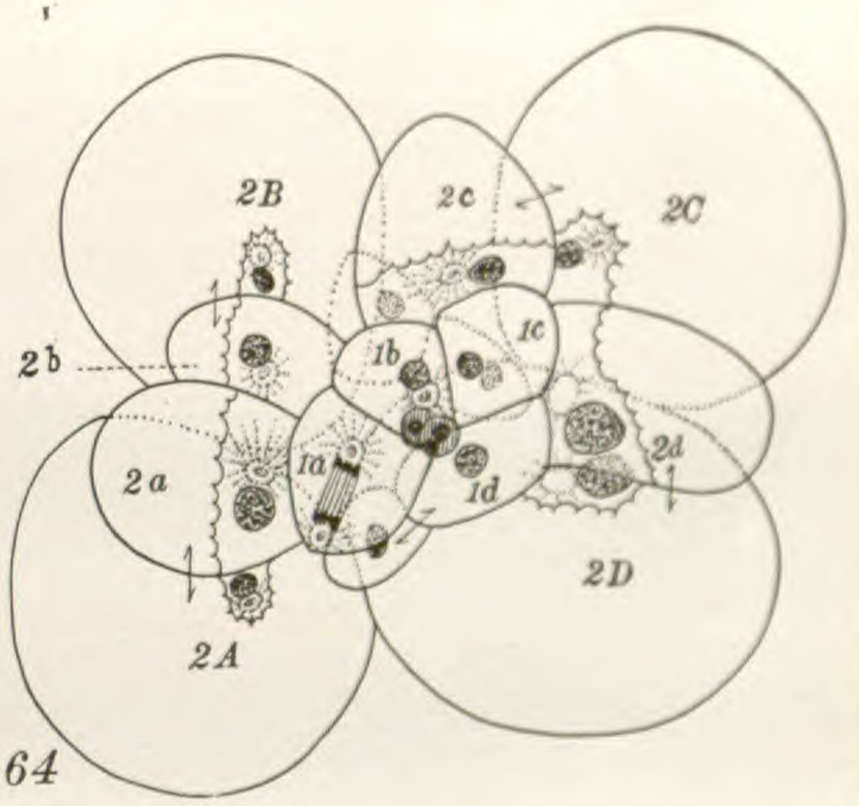

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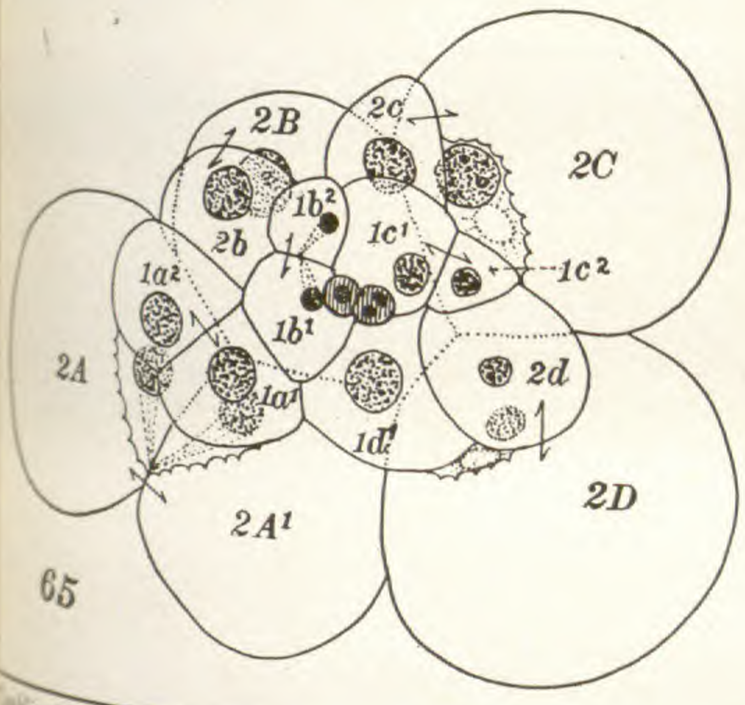

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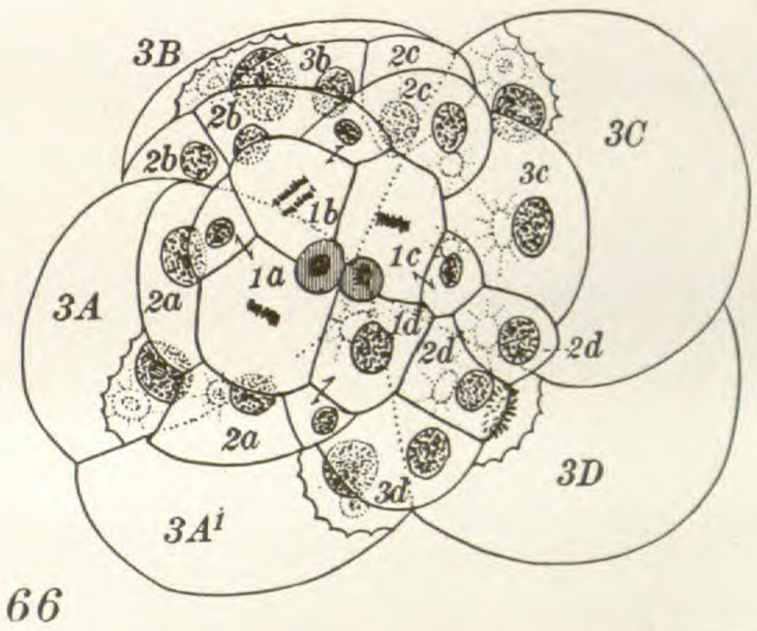

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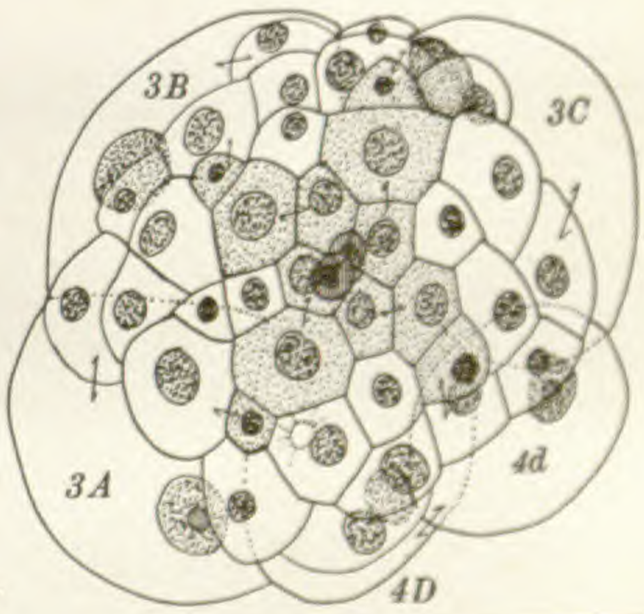


67

PLATE XLVIII.

Effects of Electric Current.

Eggs subjected to electric current (except figs. 76, 77) but probably showing effects of pressure.

Fig. 68. Exp. 1104 (?): 5 mil. amp., 5 min. First maturation spindle; the mitotic figure is much longer than normal, is central in the egg and the spindle fibres, centrosomes and astral rays are either lacking or very faint. The position is probably due to pressure.

Fig. 69. Exp. 1121 (2): 5 mil. amp. 10 min., normal 3½ hrs. Second cleavage spindles abnormal in position, first cleavage furrow incomplete, development stopped.

Fig. 70. Exp. 1121 (2): Similar to preceding.

Fig. 71. Exp. 1121 (2): Similar to preceding.

Fig. 72. Exp. 1121 (2): Similar to preceding.

Fig. 73. Exp. 1121 (2): Two cells, one containing a complete amphiaster but without any chromatin, the other containing two nuclei and one sphere, probably as the result of pressure at the close of the 1st cleavage.

Fig. 74. Exp. 1121 (2): Second cleavage spindle abnormal in position and division delayed in one blastomere.

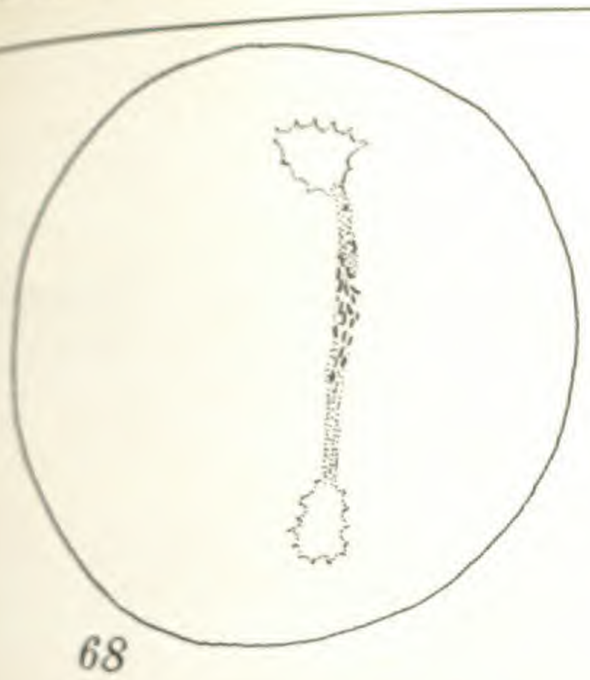
Fig. 75. Exp. 1121 (2): Three macromeres in a linear series, the middle one containing two separate cytoplasmic areas, nuclei and spheres, the result of the suppression of the first cleavage, as in fig. 72.

Fig. 76. Exp. 1001 (3): A pressure experiment included in this plate by mistake, showing eight macromeres and eight micromeres.

Fig. 77. Exp. 919: Egg subjected to pressure, probably after formation of 1st set of micromeres. In quadrant *B* and *D* the 2d set of "micromeres" are really macromeres.

Fig. 78. Exp. 1110 (2): 5 mil. amp., 2 min., normal 22 hrs. Egg with scattered blastomeres in the stage of the formation of the 2d set of micromeres.

Fig. 79. Exp. 1121 (3): 5 mil. amp., 10 min., normal 16 hrs. Egg in stage of formation of 2d set of micromeres, showing effects of pressure.



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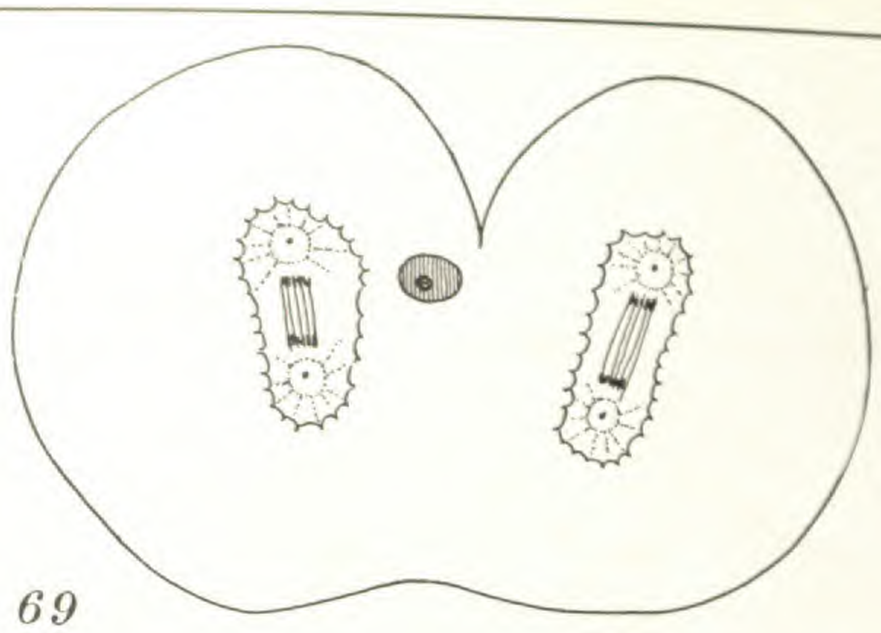

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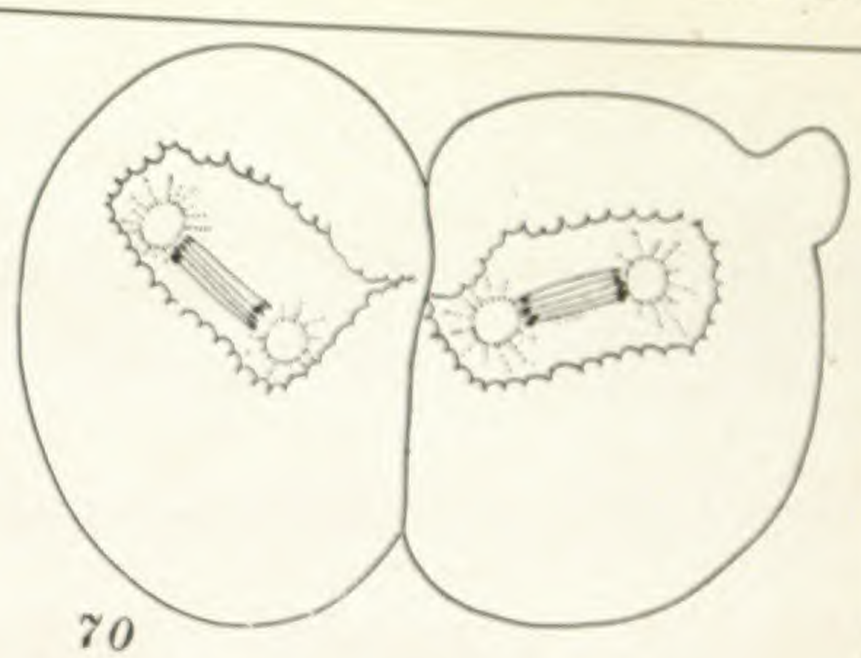

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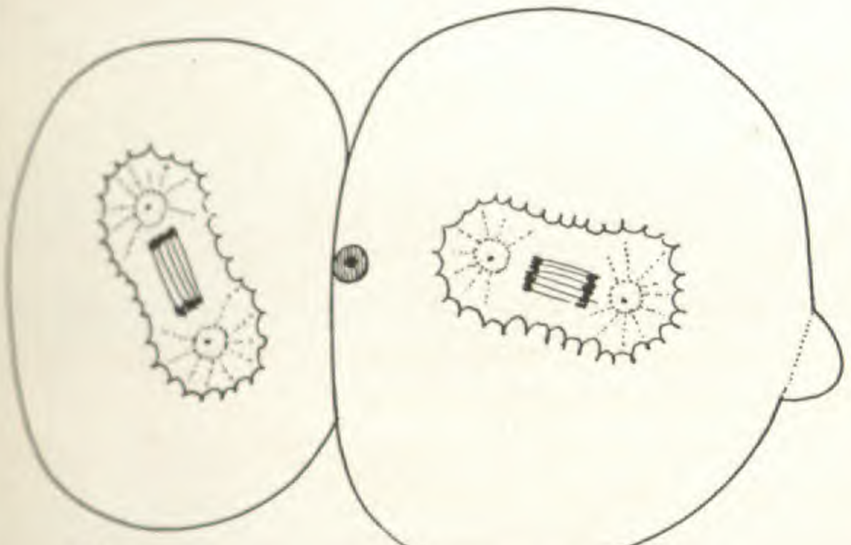

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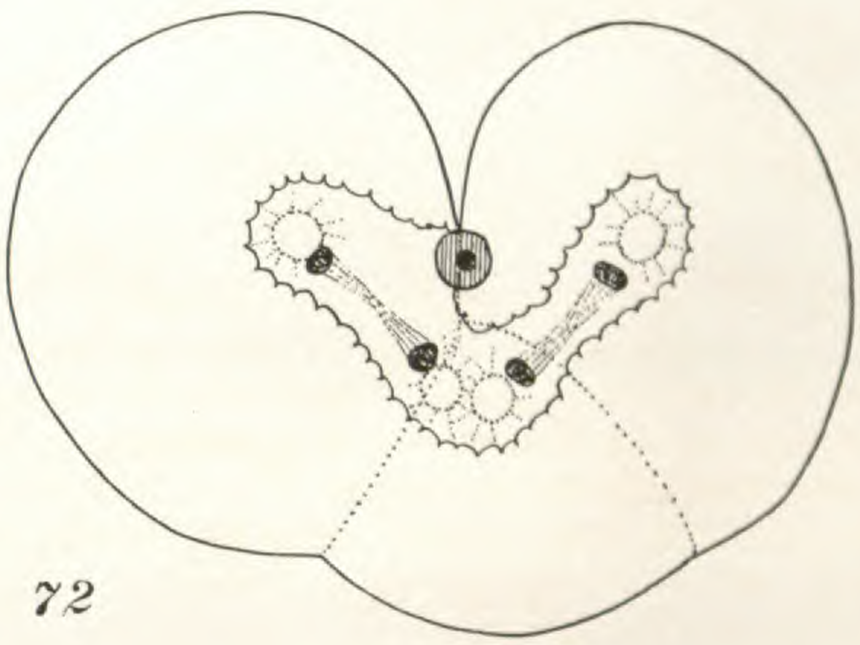

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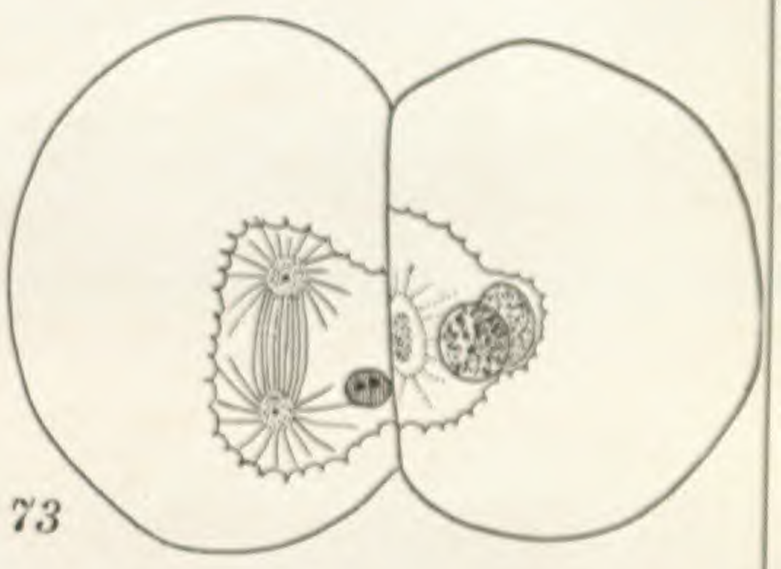

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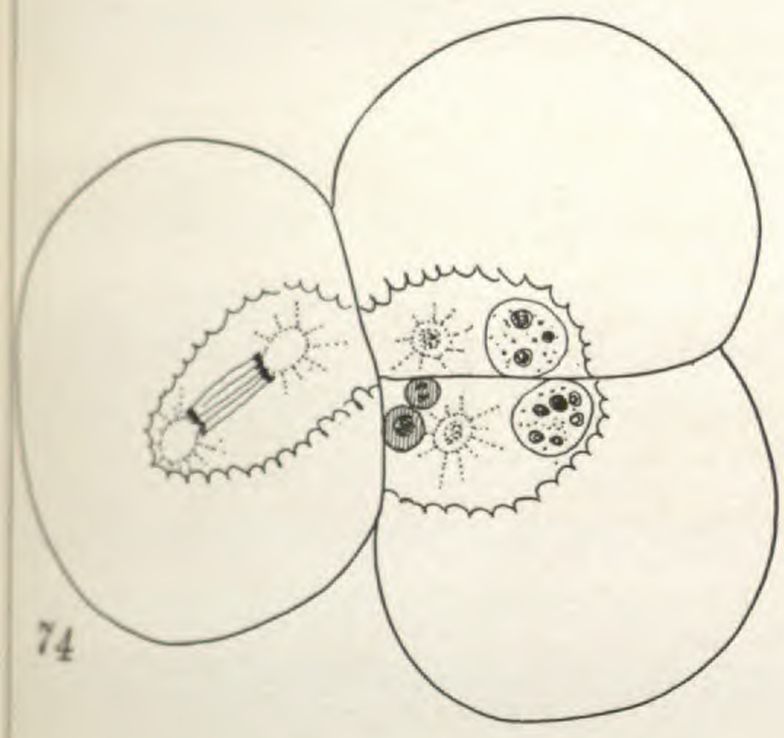

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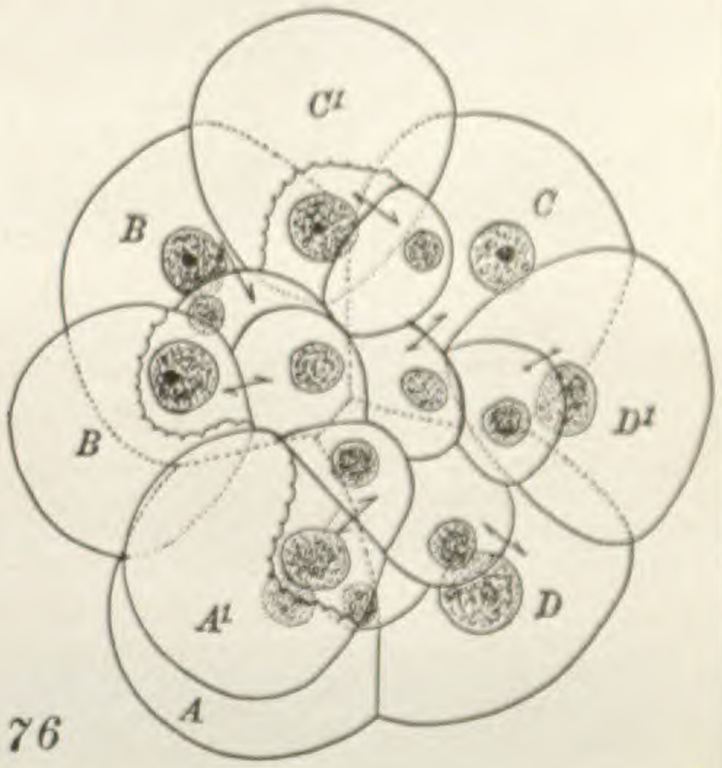

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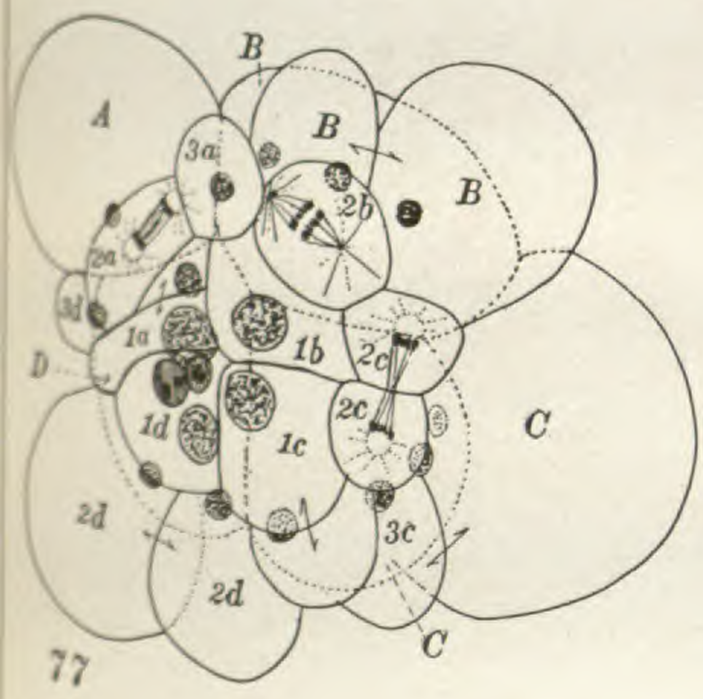

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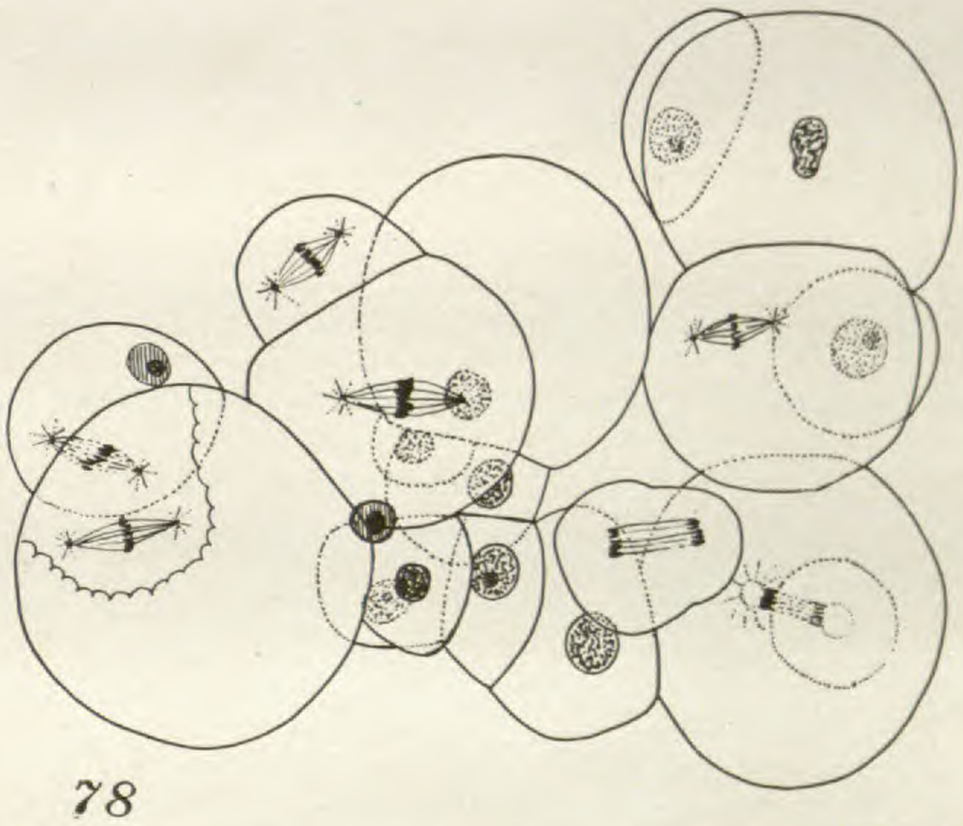

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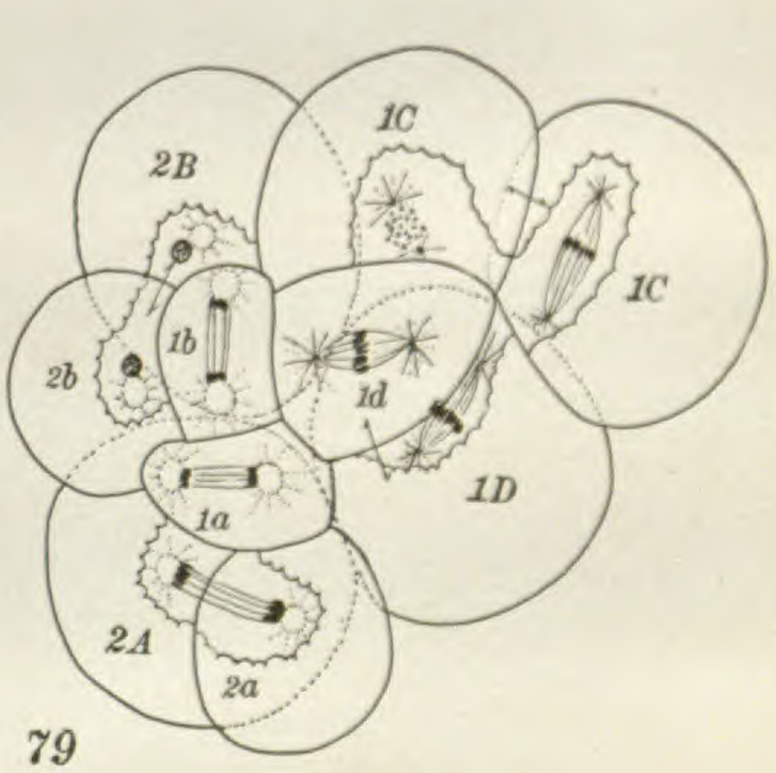


79

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

EFFECTS OF ELECTRIC CURRENT

PLATE XLIX.

Effects of Electric Current.

Fig. 80. Exp. 997 (3): 1 volt, 15 min., normal 30 min. Egg and sperm nuclei are large and contain little chromatin, sphere material in granules, no segregation of yolk and cytoplasm.

Fig. 81. Exp. 997 (3): Similar to preceding.

Fig. 82. Exp. 1106: 5 mil. amp., 5 min., normal 17 hrs.; nuclear membrane dissolved and chromatin clumped; development stopped.

Fig. 83. Exp. 1106: Similar to preceding.

Fig. 84. Exp. 1106: Similar to preceding.

Fig. 85. Exp. 997 (3): Similar to fig. 80, but with nuclear membrane gone.

Fig. 86. Exp. 1140 (1): 2 mil. amp., 2 min., normal 5½ hrs. Chromatin disappearing.

Fig. 87. Exp. 1140 (2): 5 mil. amp., 10 min. Ordinary tetraster.

Fig. 88. Exp. 997 (2): 1 volt, 15 min., normal 2½ hrs. Plasma and nuclei displaced by convection current, as in centrifuged eggs.

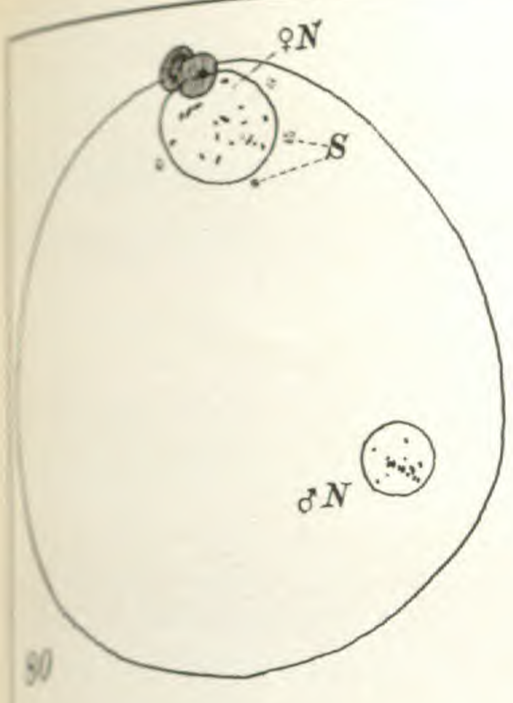
Fig. 89. Exp. 997 (2): Similar to preceding.

Fig. 90. Exp. 1121 (2): Chromosomes have disappeared leaving the spindle fibers a little more chromatic than in normal eggs.

Fig. 91. Exp. 997 (2): 1 volt, 15 min., normal 2½ hrs. Chromatin largely dissolved and displaced toward lower pole; in right cell long strands of cytoplasm.

Fig. 92. Exp. 1121 (2): 5 mil. amp., 10 min., normal 3½ hrs. Spindle and chromosomes disappearing in left cell; others normal.

Fig. 93. Exp. 998 (2): 4 dry cells 1¾ hrs., normal 11 hrs. Evidently egg was in an advanced stage (ca. 42 cells) at the time of the experiment. Although the cells are not dead, the micromeres are rounded (framboisia) and many have dropped off.



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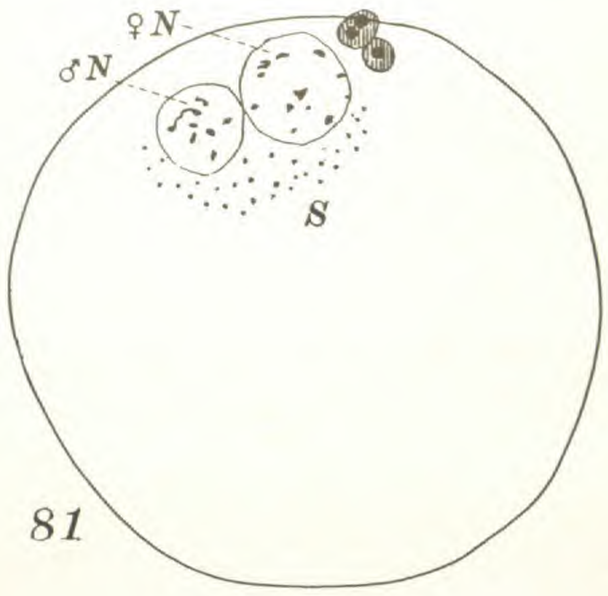

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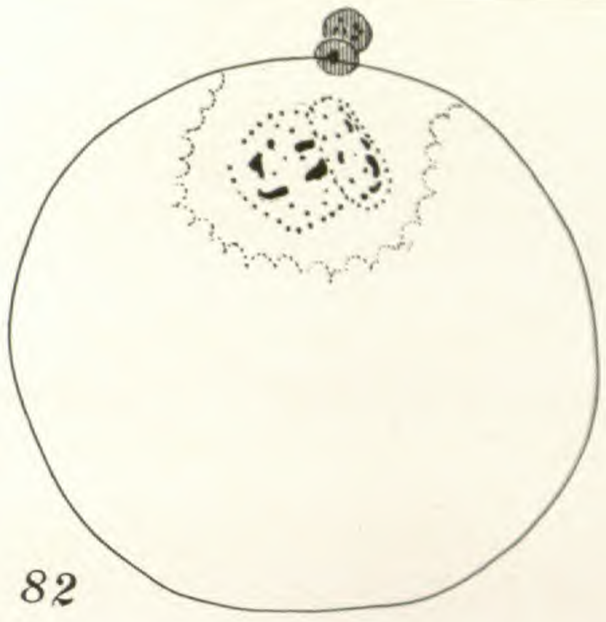

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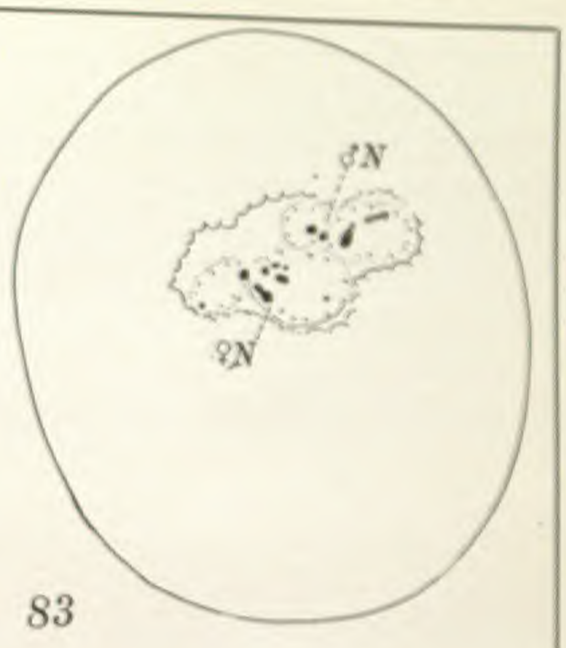

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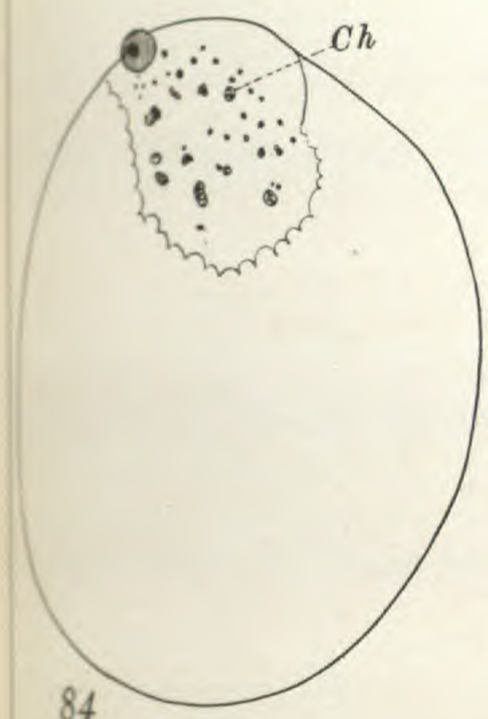

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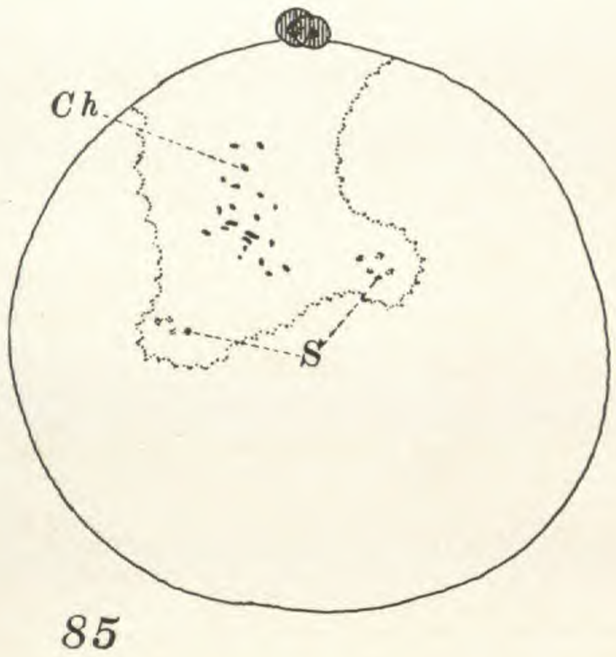

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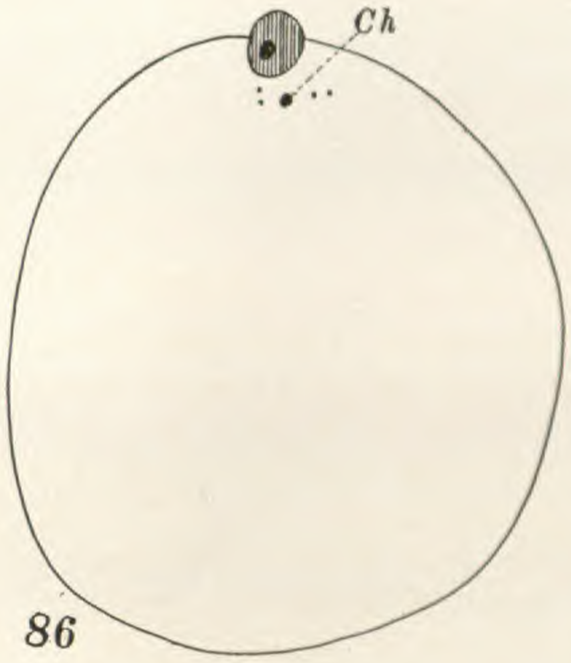

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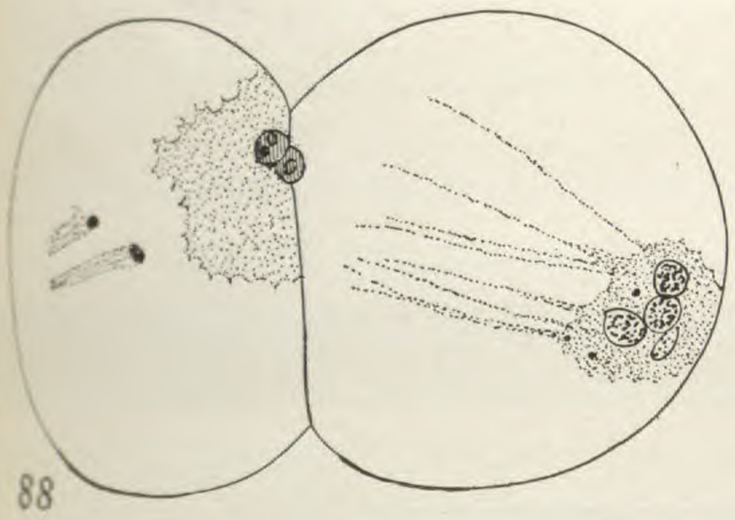

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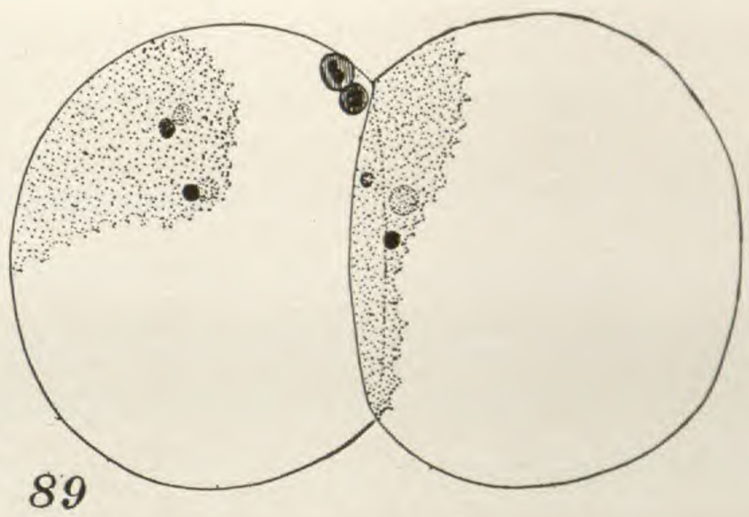

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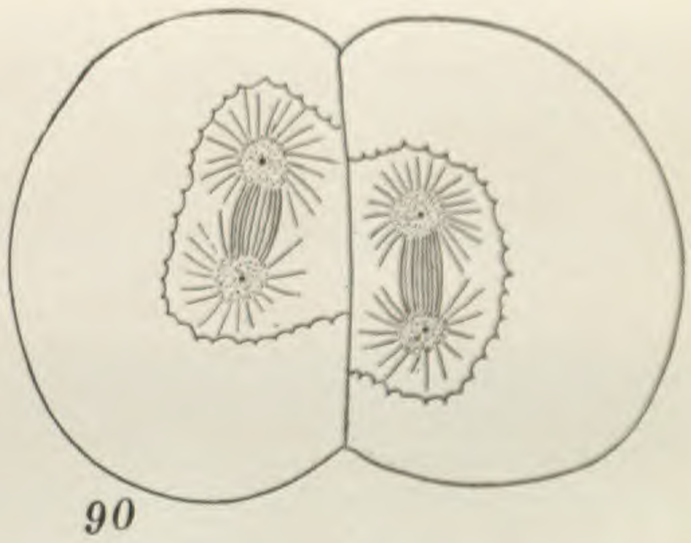

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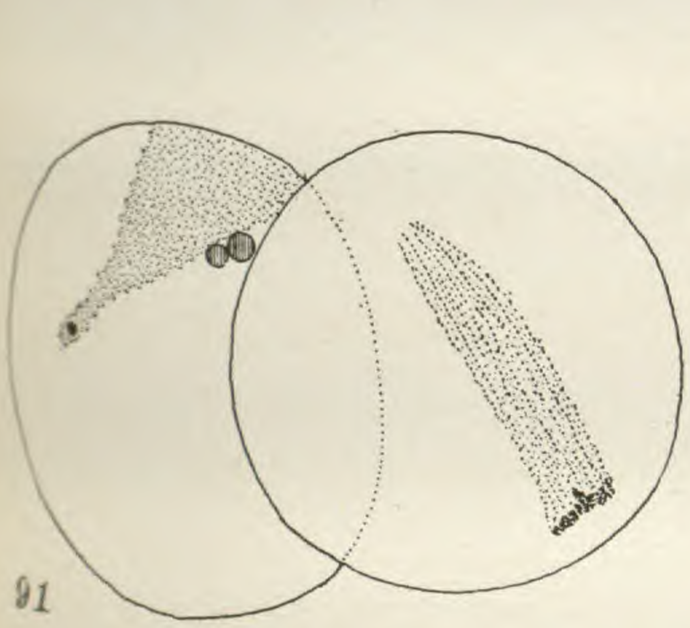

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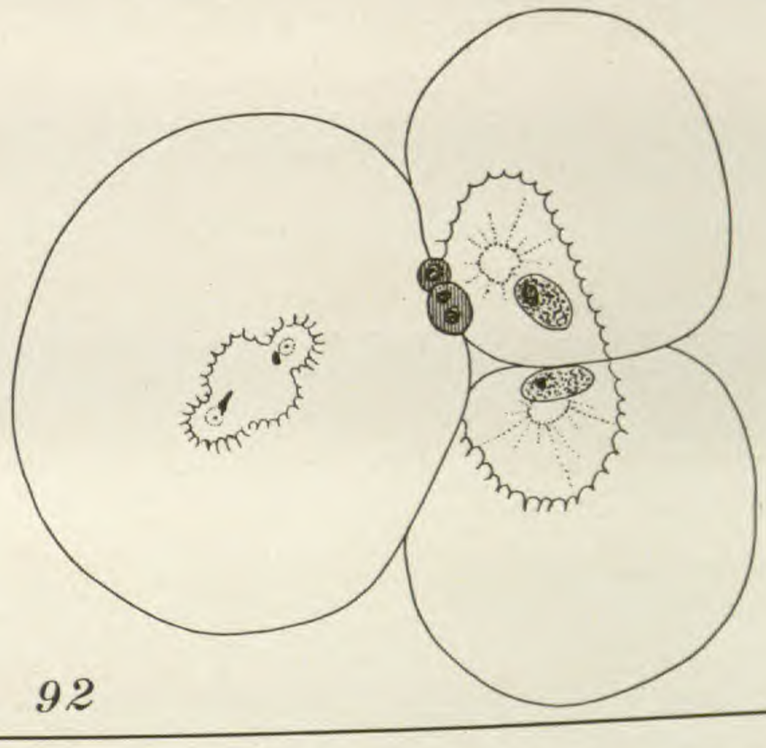

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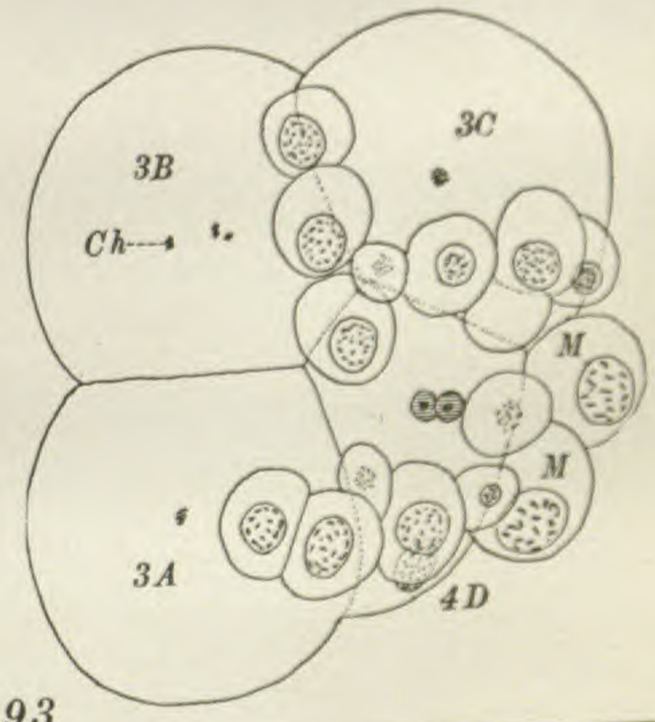


93

Conklin del.

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

EFFECTS OF ELECTRIC CURRENT

PLATE L.

Effects of Abnormal Temperature.

Fig. 94. Exp. 1170 (1): Ca. 38° C. 1 hr.; egg irregular in outline, with archiplasm withdrawn into amphiaster, and into the surface layer. First maturation amphiaster irregular in shape and chromosomes scattered; sperm nucleus near vegetal pole.

Fig. 95. Exp. 1174 (2): 37° C. ¼ hr., room temp. (27°) 3 hrs.; first polar body very large; chromosomes of second maturation division have formed karyomeres; sperm nucleus near animal pole.

Fig. 96. Exp. 1171 (1): Ca. 35° C. ½ hr.; 2-cell stage, showing dense aggregation of archiplasm around nuclei and spheres, with different kinds of cytoplasm in other parts of cell.

Fig. 97. Exp. 1171 (1): Similar to preceding; second cleavage spindles greatly modified; chromosomes scattered; archiplasm gathered in spindle areas and division wall.

Fig. 98. Exp. 1171 (2): Ca. 35° C. ½ hr., room temp. (ca. 24°–26°) 15 hrs.; the archiplasm has collected in central areas in each cell and in division walls; chromosomes are clumped and thrown out of cytoplasmic areas.

Fig. 99. Exp. 1171 (2): Similar to preceding.

Fig. 100. Exp. 962: On ice 16 hrs.; the spheres of the third cleavage are unusually distinct and the scattered sphere granules of the second cleavage (in the micromeres) are very large.

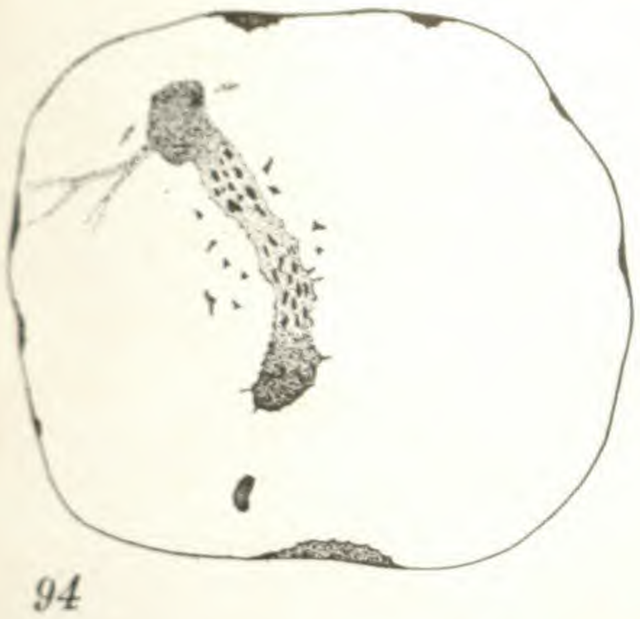
Fig. 101. Exp. 962: The spheres have a definite boundary, stain more deeply than usual and look almost like nuclei.

Fig. 102. Exp. 962: A later stage, with spheres similar to those shown in fig. 101.

Fig. 103. Exp. 964: On ice 40 hrs.; the sphere granules are especially large.

Fig. 104. Exp. 964: Similar to preceding.

Fig. 105. Exp. 964: Similar to preceding; many of the sphere granules are vesicular.



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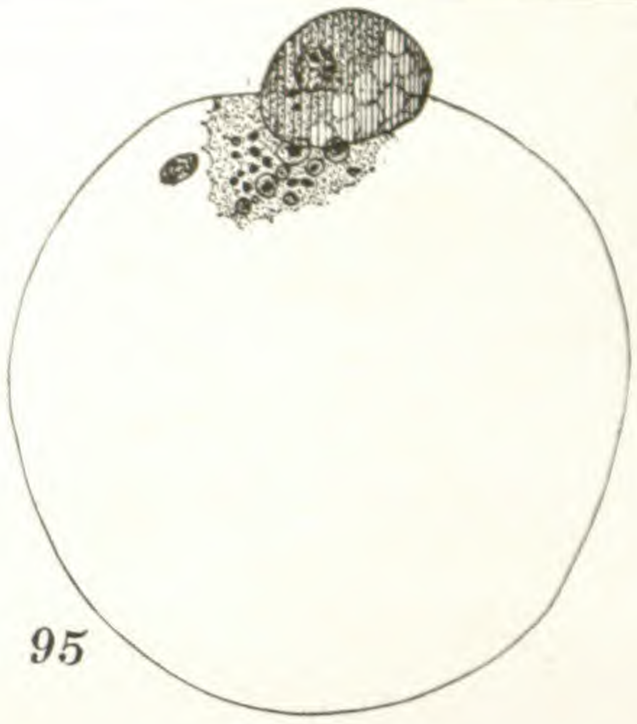

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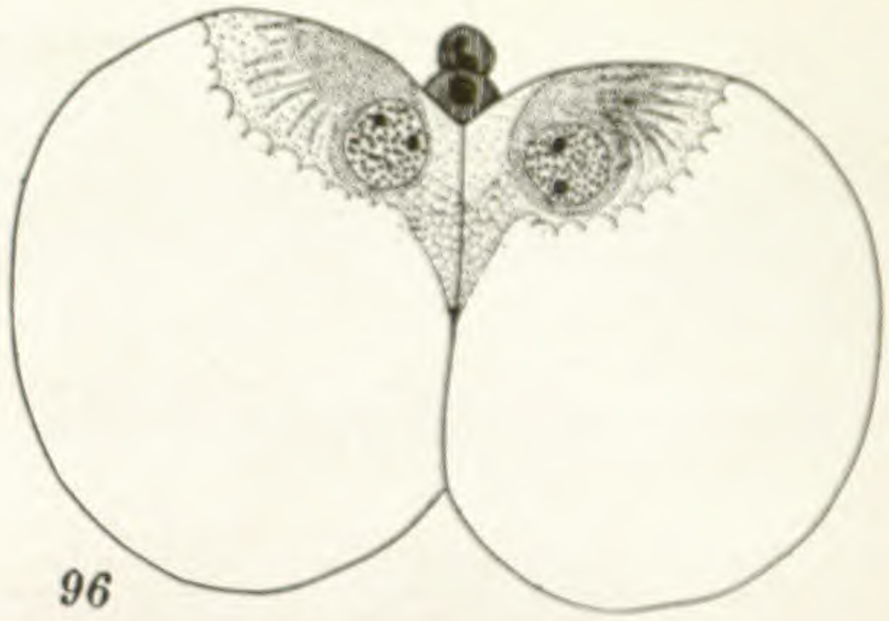

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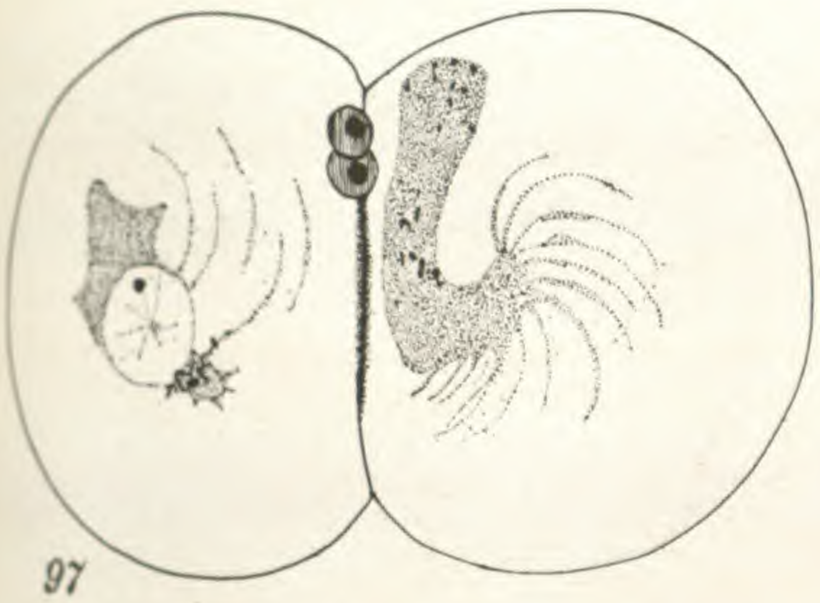

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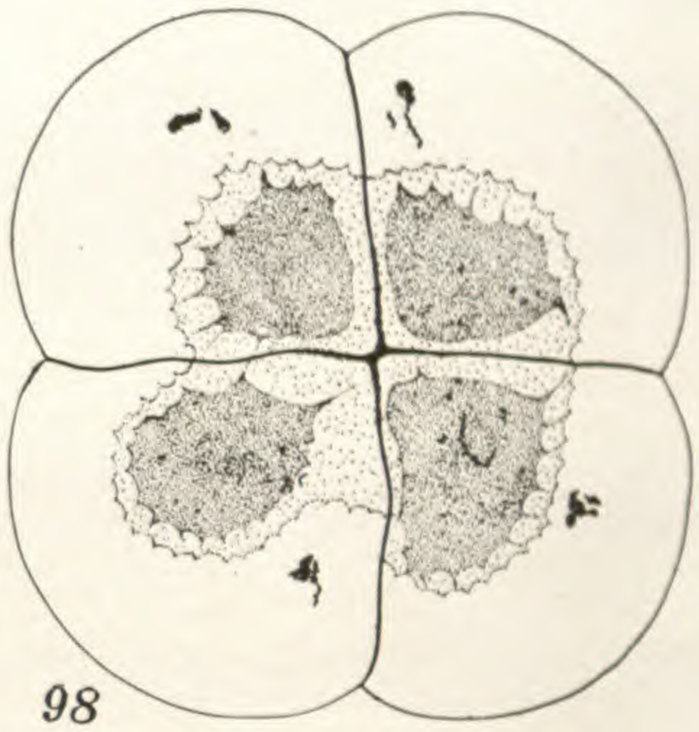

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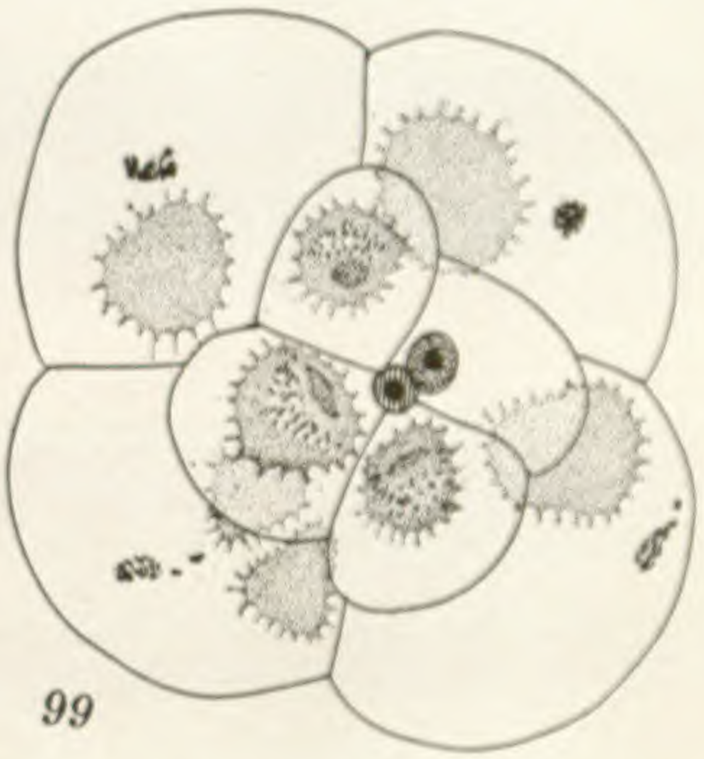

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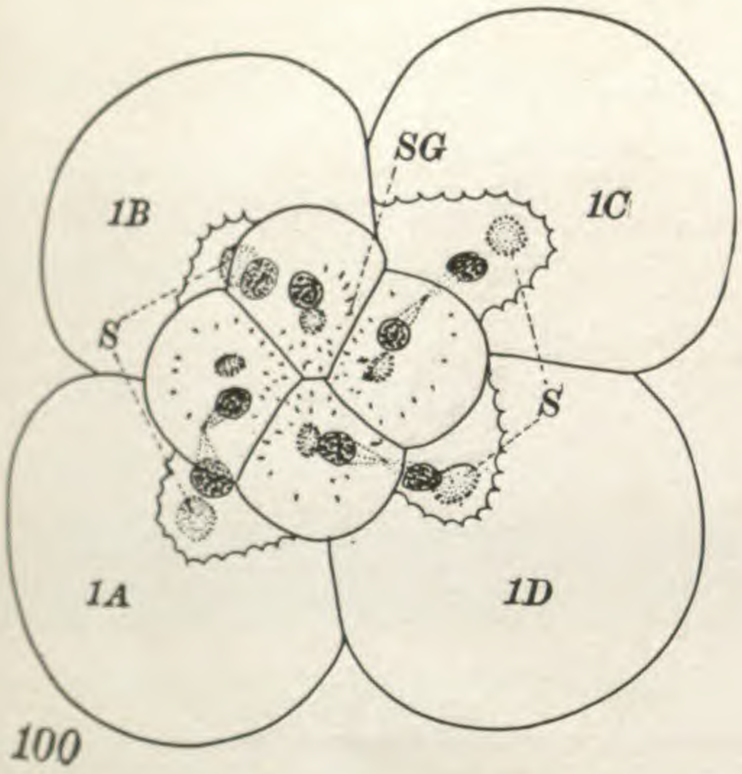

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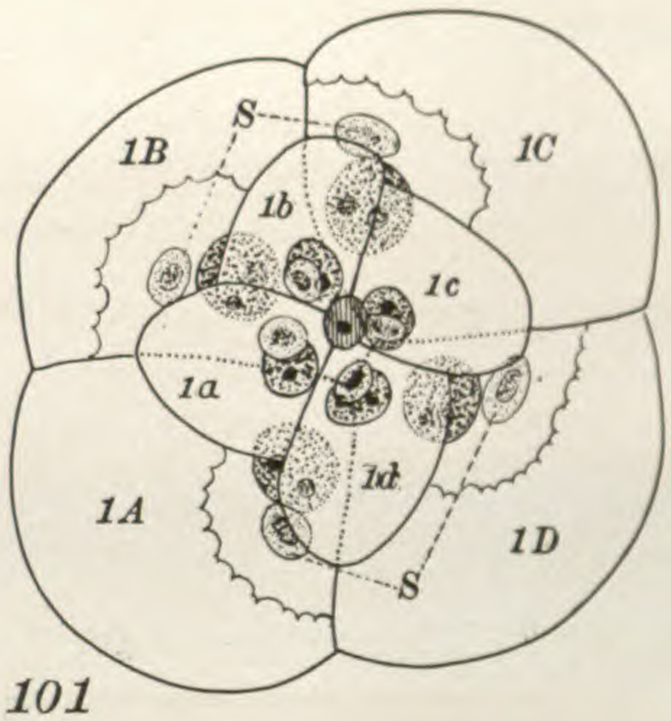

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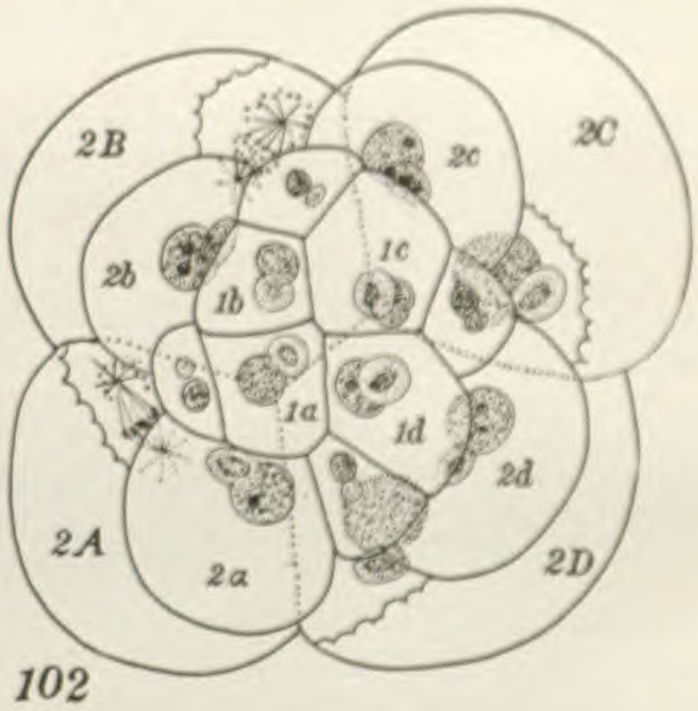

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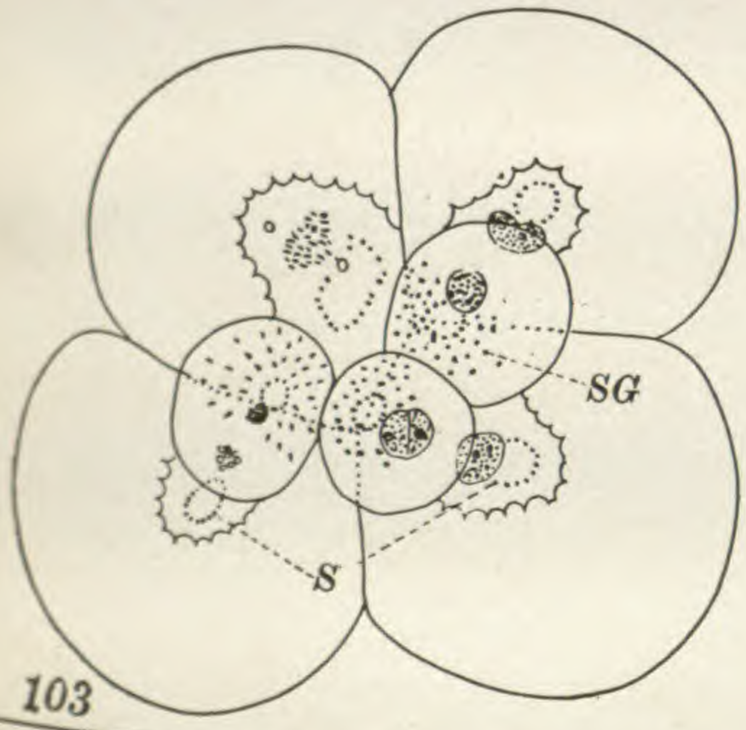

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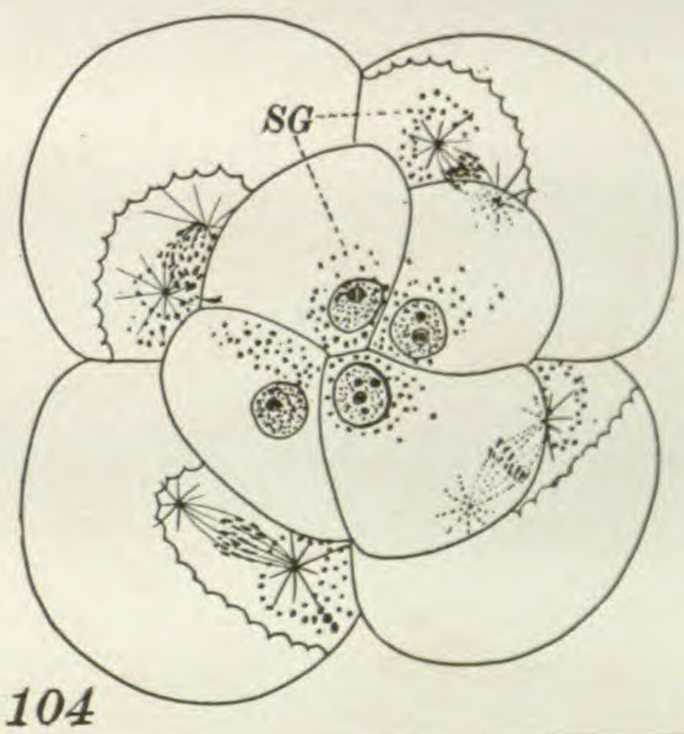

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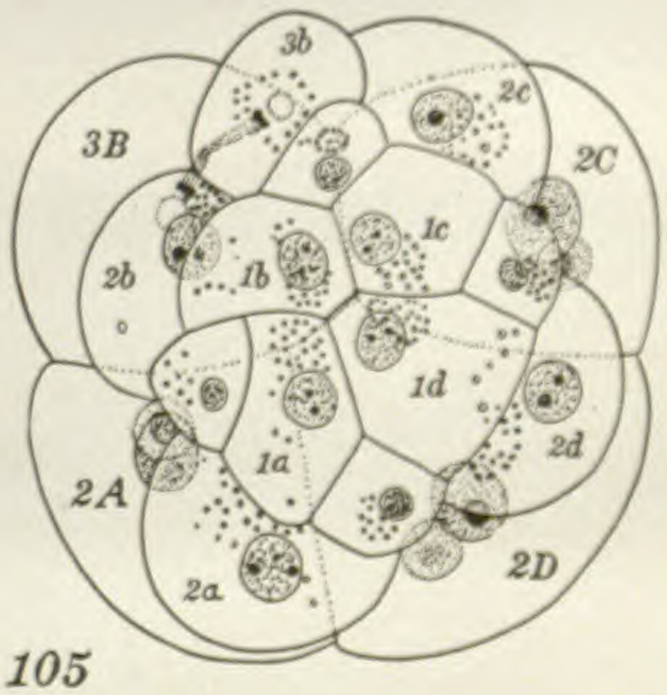


105

Conklin del.

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

EFFECTS OF ABNORMAL TEMPERATURES

PLATE LI.

Effects of Decreased Oxygen Tension.

Figs. 106–109. Exp. 1010: Eggs placed for 36 hrs. in sea water which had been boiled to drive off contained gases, and then cooled; all development was completely stopped, but eggs were not killed; chromatin in the resting nuclei is collected into one or more masses; spindle fibres are distinct but astral rays are lacking; centrosomes and sphere granules are vesicular. The eggs used in this experiment were much smaller than normal, being only 120 μ in diameter.

Figs. 110–111. Exp. 1025: Eggs left for 18 hrs. in a stoppered bottle of sea water, through which hydrogen had been run for 1 hr.; development completely stopped; nuclei and nucleoli large, little chromatin.

Fig. 112. Exp. 1016: Eggs placed for 27 hrs. in sea water which had been boiled and cooled; similar to preceding, development stopped.

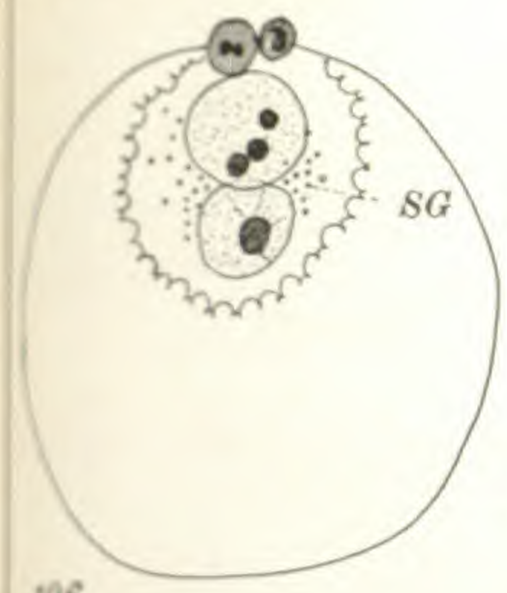
Fig. 113. Exp. 1017: Eggs left for 48 hrs. in stoppered test tube of boiled and cooled sea water; development completely stopped; sphere granules prominent.

Fig. 114. Exp. 1016: Same as fig. 112; nuclei with little chromatin; sphere granules prominent.

Fig. 115. Exp. 1023: Eggs subjected to atmosphere of hydrogen for 2 hrs. and then left in open bottle for 2 hrs.; development stopped; eggs similar to all others subjected to decreased oxygen tension.

Fig. 116. Exp. 1017: Same as in fig. 113: The spindles are small, deep-staining and without astral rays; the chromosomes are arranged in a ring around the spindles.

Figs. 117–118. Exp. 1025: Eggs left for 18 hrs. in stoppered bottle of sea water through which hydrogen had been run for 1 hr.; eggs similar to fig. 115; in fig. 118 there is an area of yolk (*Y*) around the upper poles of the spindles.



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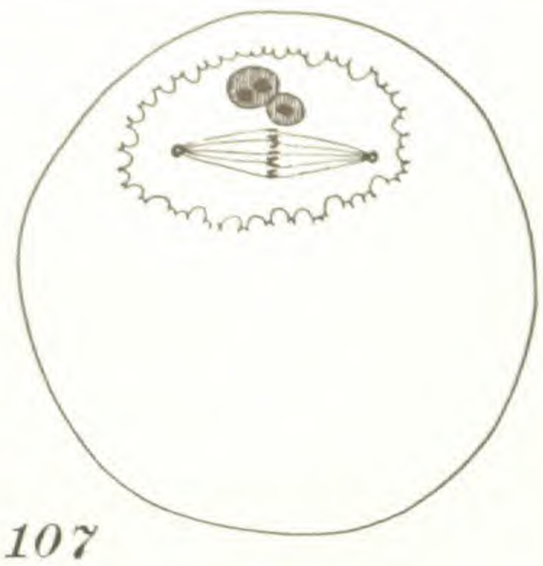

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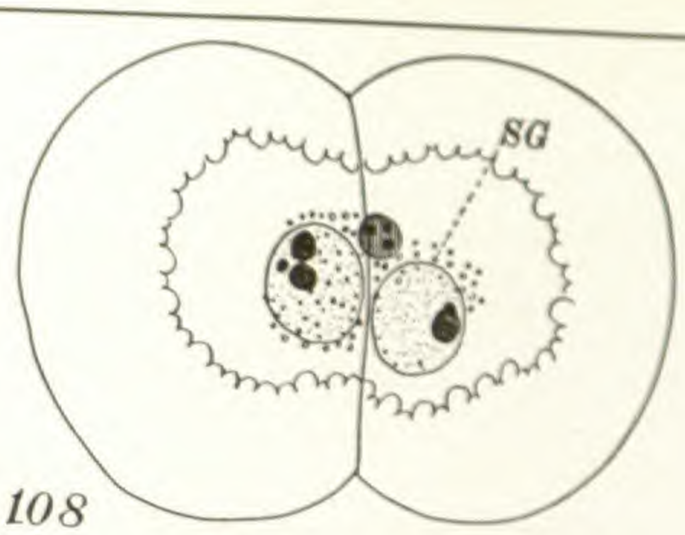

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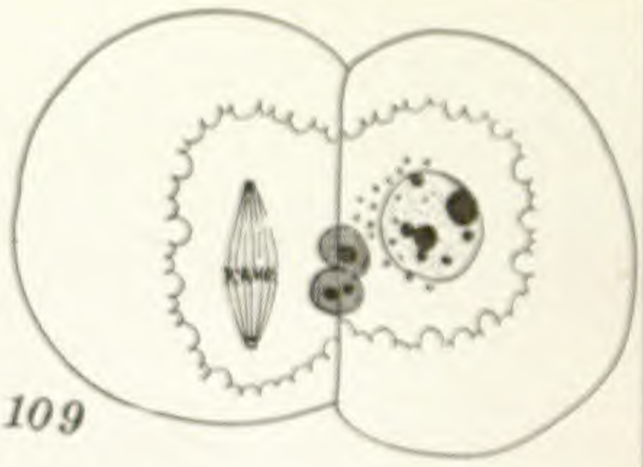

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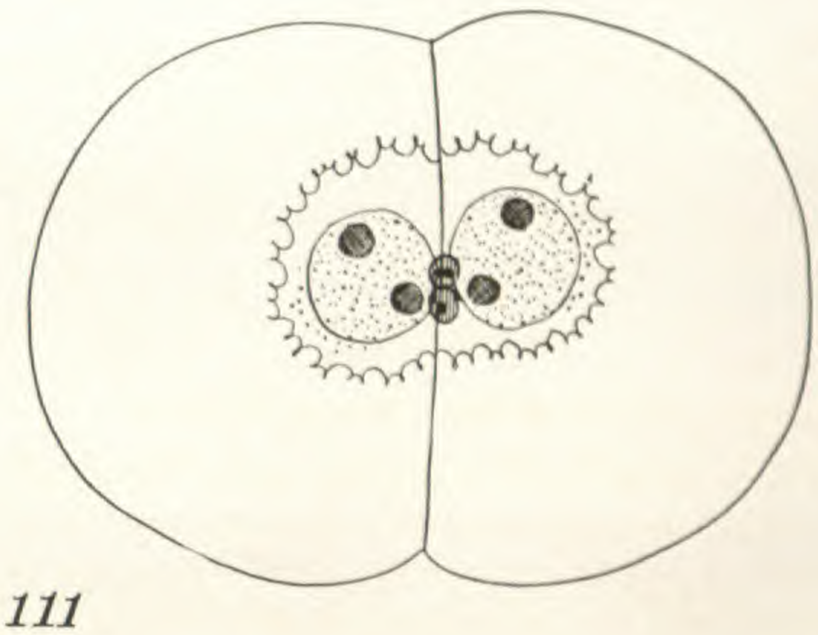

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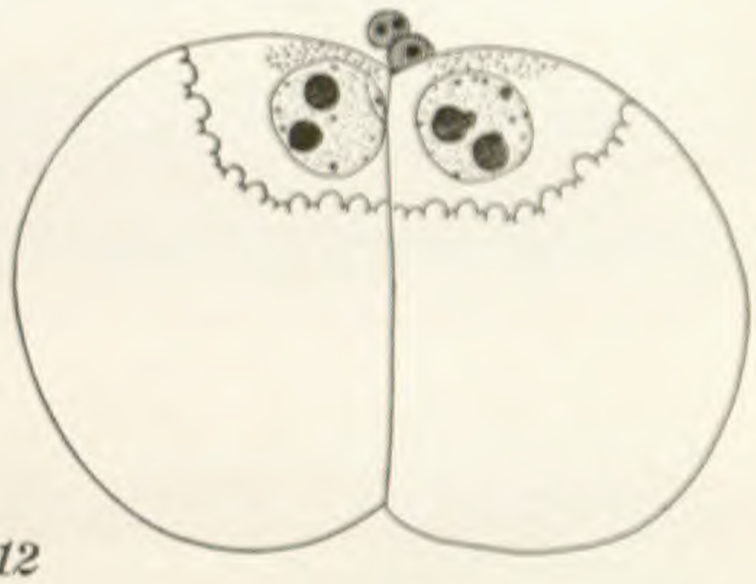

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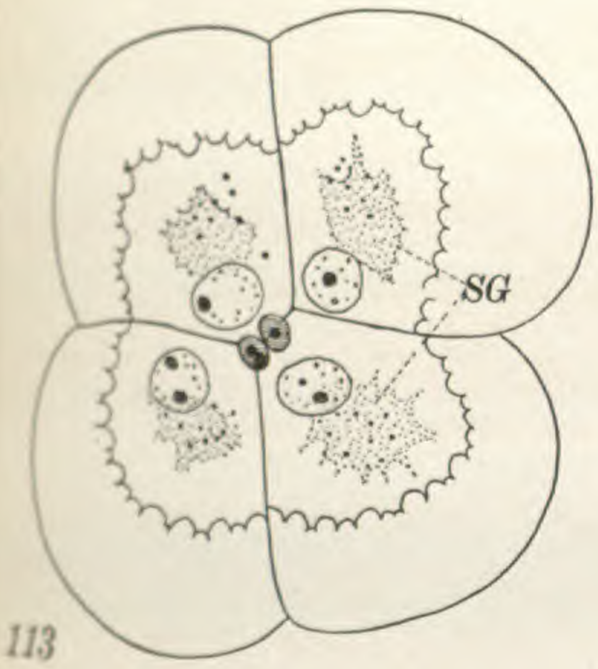

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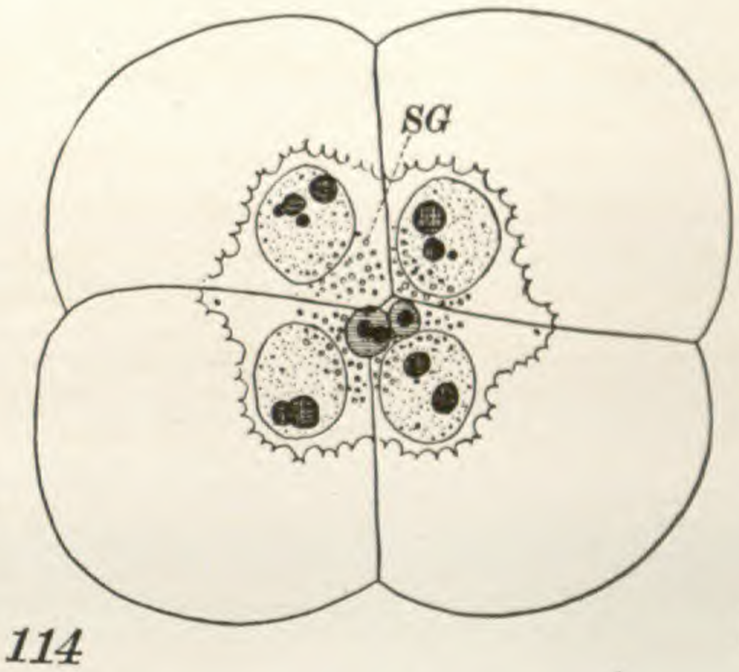

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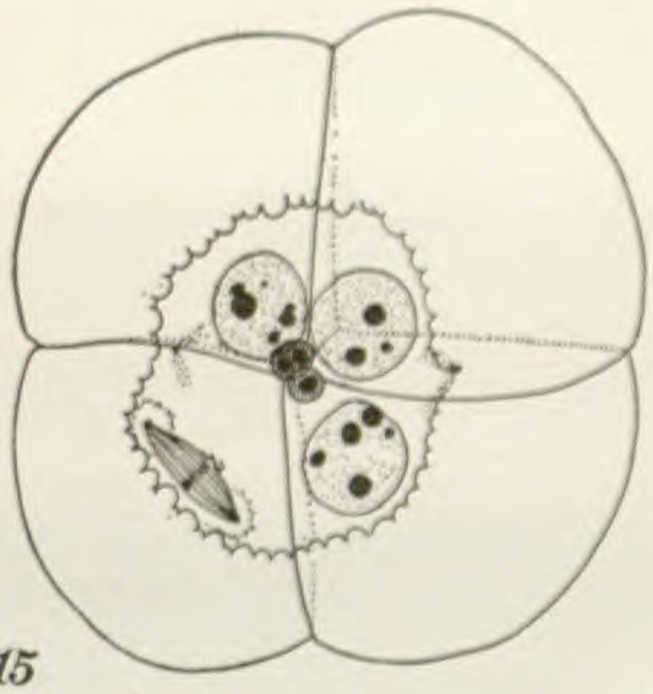

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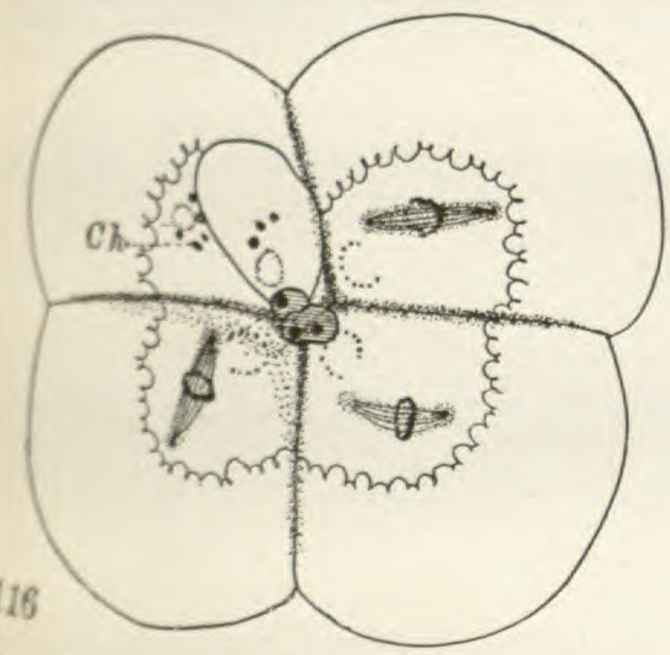

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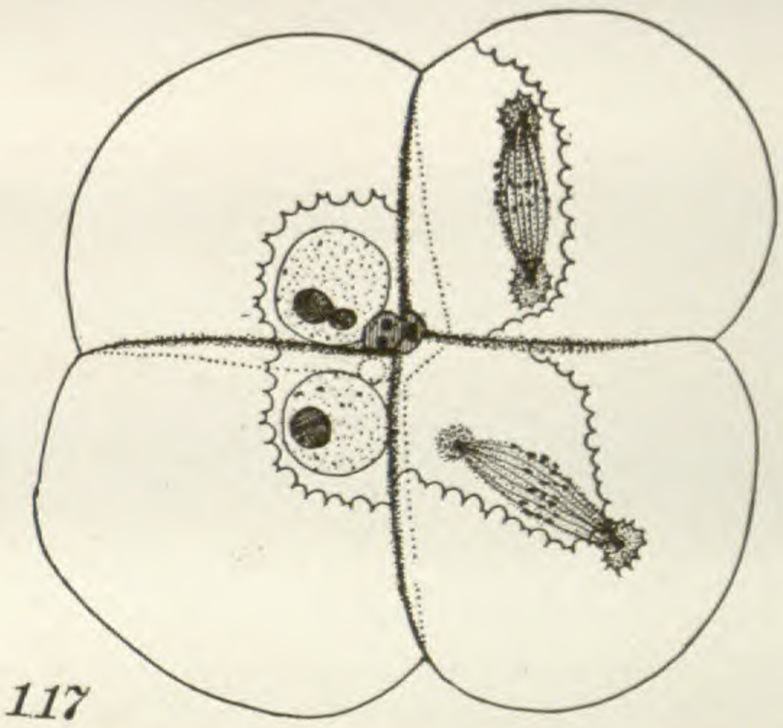

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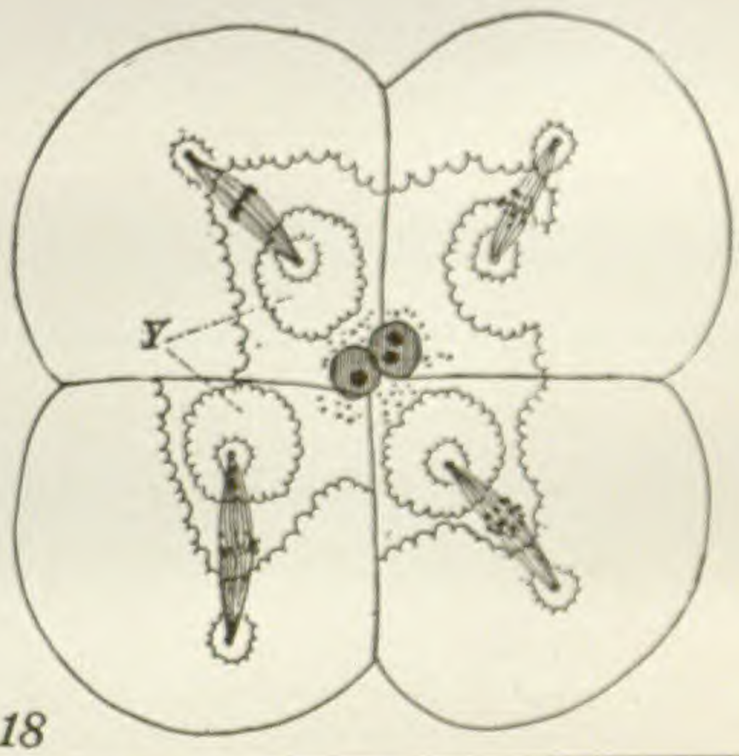


118

Conklin del.

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

DECREASED OXYGEN TENSION

PLATE LII.

Effects of Carbonic Acid.

Eggs in 1–8-cell stage left for 28 hrs. in sea water ½ saturated with CO_2.

Fig. 119. Exp. 1163: Egg showing the individually distinct chromosomal vesicles of the maturation divisions; also the cell membrane separated from the subjacent egg substance.

Fig. 120. Exp. 1163: Eggs showing five protoplasmic cells (one of them with four nuclei) on the unsegmented yolk.

Fig. 121. Exp. 1164: Side view of an egg similar to the preceding.

Fig. 122. Exp. 1163: The second polar body is abnormally large; an accessory aster (*S*) lies in the yolk; the division of the nucleus in the 1st cleavage has taken place normally, though the spheres are prevented from moving to their normal positions above the nuclei by the presence of the large polar body; the cleavage furrow cuts into the egg from the animal pole side only, and ends in a "cleavage head" as in cœlenterate eggs.

Fig. 123. Exp. 1163: The *C* and *D* quadrants are entirely normal; in the blastomere *AB*, the nucleus divided but the cell did not; these two nuclei in an undivided cell gave off a single blastomere of the first set (1*ab*) with large lobulated nucleus, the nuclei, spheres and cytoplasmic areas of the cell *AB* then came to lie at opposite sides of the macromere and each divided independently giving rise to a second micromere (2*a*, 2*b*) which is nearly normal.

Fig. 124. Exp. 1163: There are three macromeres one of which contains a perfect spindle but no chromatin; another contains a polyaster and has given off a large micromere with three nuclei; the third contains a single nucleus which is smaller than normal and has given off in reversed cleavage a 1st and a 2d micromere, the former of which is dividing.

Fig. 125. Exp. 1163: The first cleavage furrow failed to appear though the nuclei divided; at the 2d cleavage each nucleus with its adjacent oöplasm gave off a smaller macromere (*B* and *D*), leaving macromeres *A* and *C* still undivided; each of these four macromeres has given off a micromere of the 1st set.

Fig. 126. Exp. 1163: Three macromeres one of which contains several centrosomes and spheres (*S*) but no nucleus; another contains a bifurcated spindle and a normal one and has just given off two micromeres one on the right and one on the left; the other macromere contains a single nucleus and sphere and has just given off a micromere on the right; two large micromeres with abnormal nuclei occupy the center of the micromere field. There is a general resemblance of this egg to that shown in fig. 124.

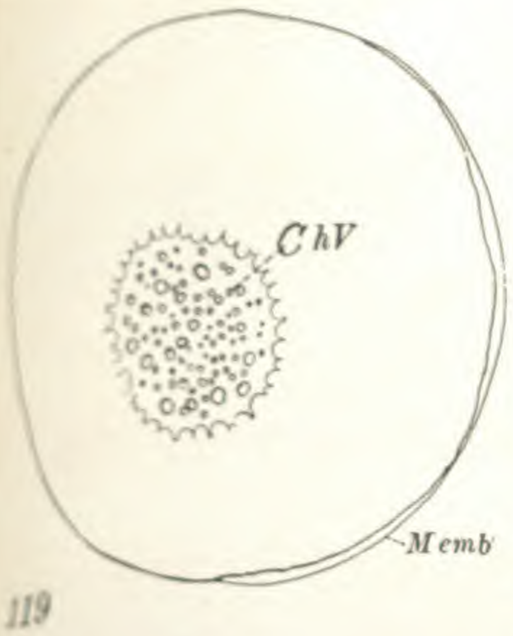
Fig. 127. Exp. 1163: Side view of egg with two macromeres and several micromeres. Strands of protoplasm run from the polar bodies to the micromeres and from one of the latter to a macromere, suggesting the "spinning" activities of other eggs; lobes are also found on several cells.

Fig. 128. Exp. 1163: Two macromeres, each with two nuclei and two or more spheres; in the second cleavage the nuclei divided but the cell-body did not; in the third cleavage there was probably a triaster in each macromere, since only two micromeres of the first set were formed (1*ab*, 1*cd*) each with multiple nuclei; in the fourth cleavage each macromere contained two separate spindles and gave off two separate micromeres (2*a*, 2*b*, 2*c*, 2*d*) of the second set; the nuclei in the macromeres are so well separated that it is probable that at the next cleavage two independent spindles would form in each macromere and would lead to the formation of four micromeres of the third set.

Fig. 129. Exp. 1163: Macromeres *A* and *B* did not separate at the 2d cleavage, but each has given rise to three micromeres forming a typical micromere plate, though the direction of division in *A* and *B* has sometimes been atypical.

Fig. 130. Exp. 1164: Irregular cleavage mass in which it is not possible to identify many cells. Several of the cells show loose membranes and lobes.

Fig. 131. Exp. 1163: One of the macromeres (*D*) was separated from the other three, but each has given rise to three micromeres which have subdivided in normal manner, the micromeres formed from *D* lying on the right of the micromere plate formed from the other macromeres.



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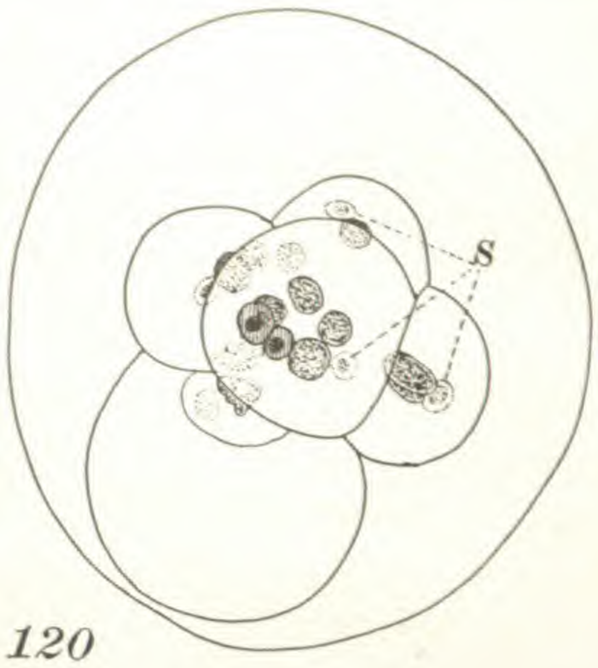

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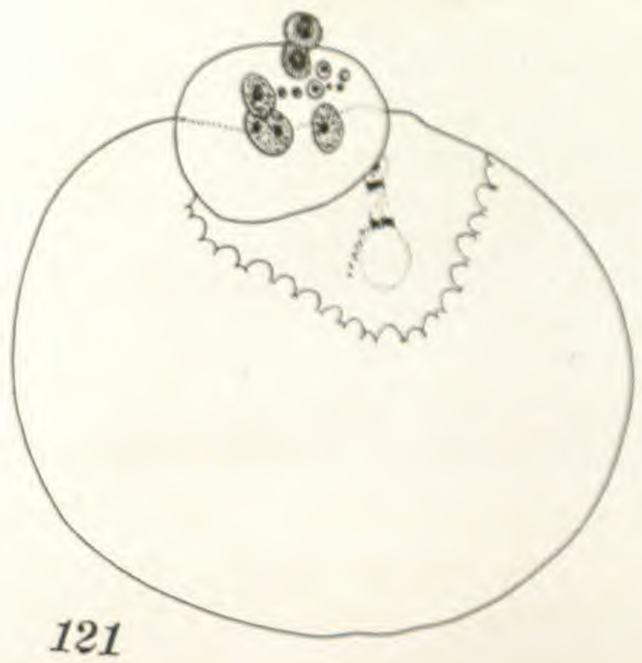

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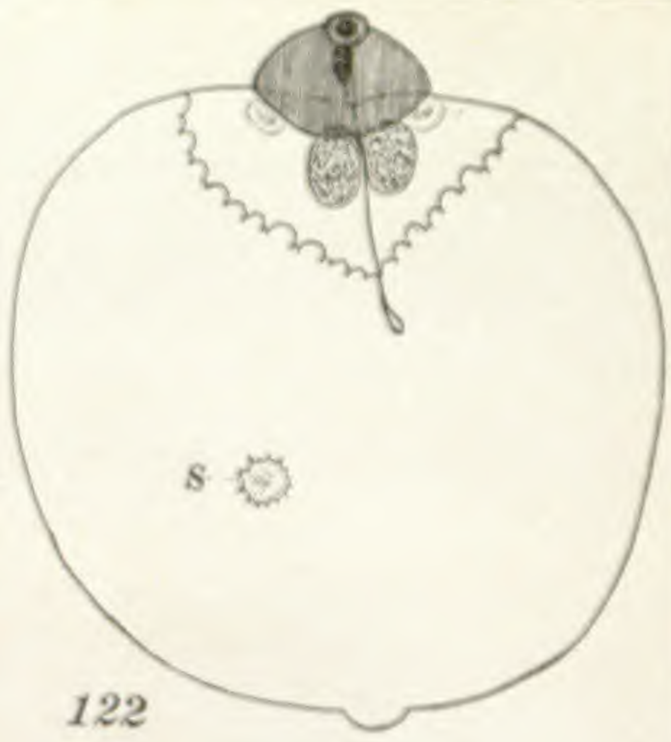

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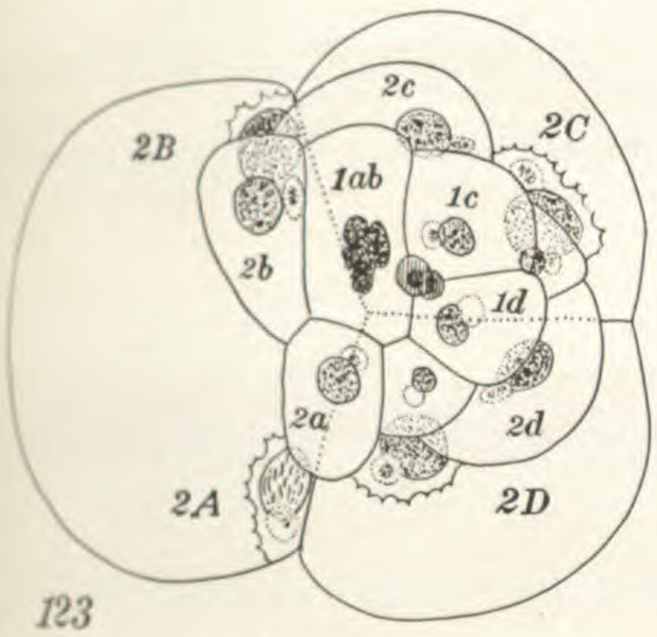

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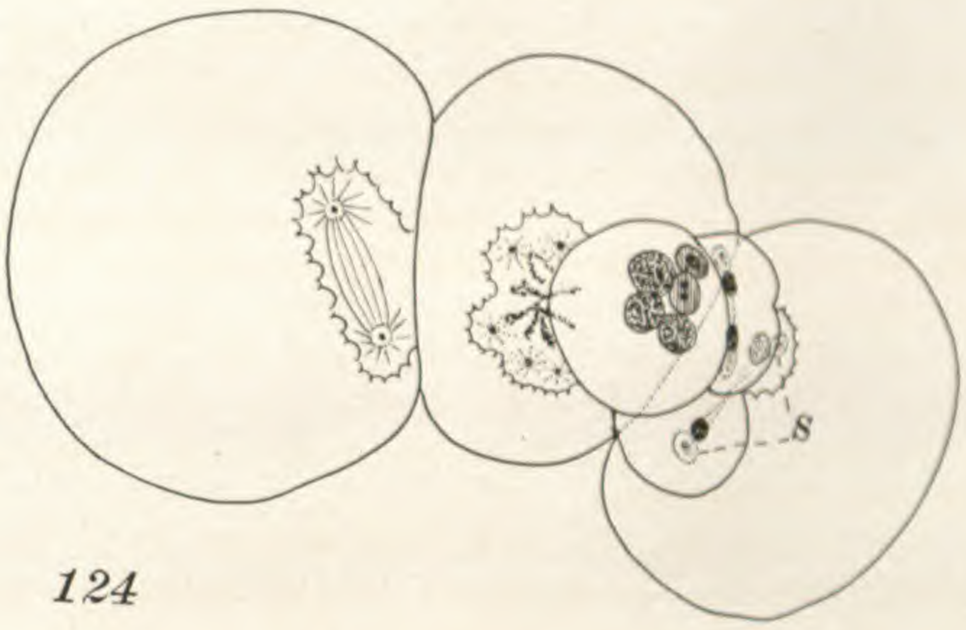

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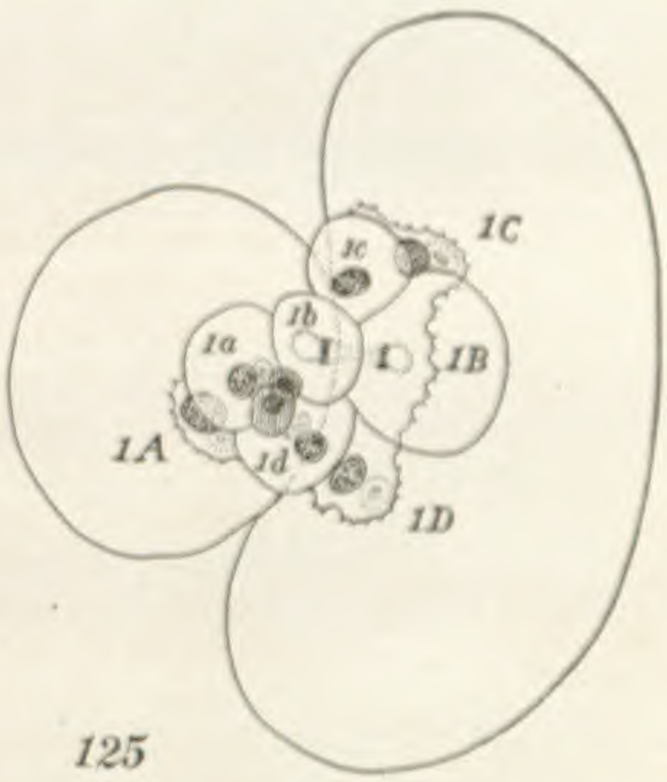

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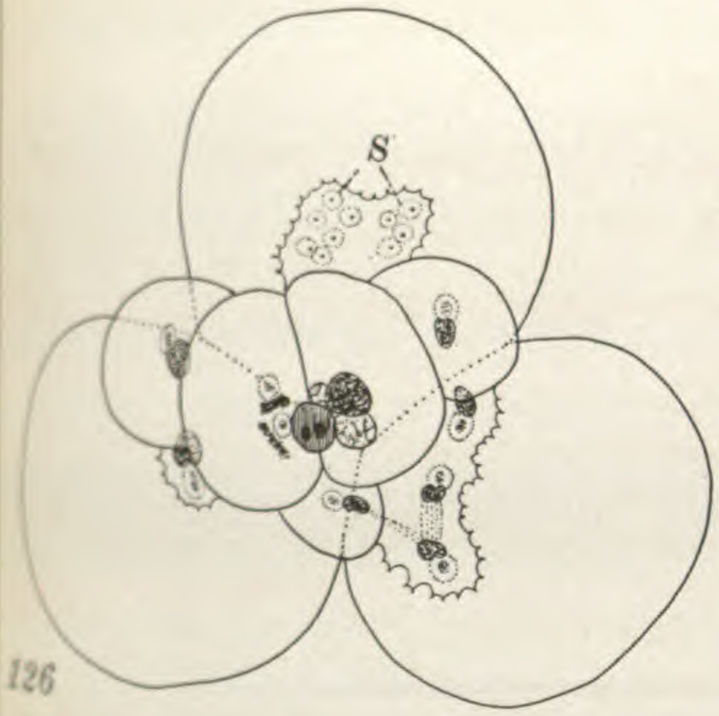

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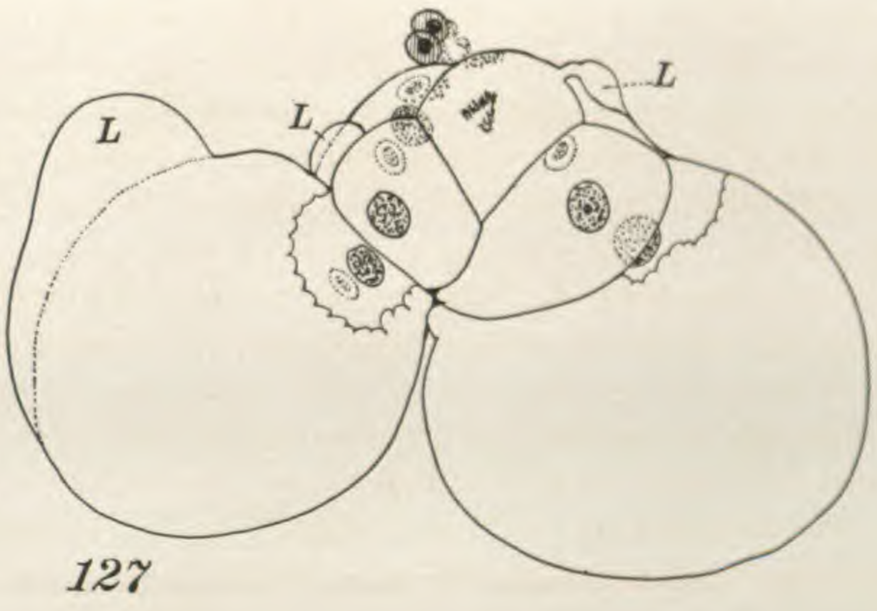

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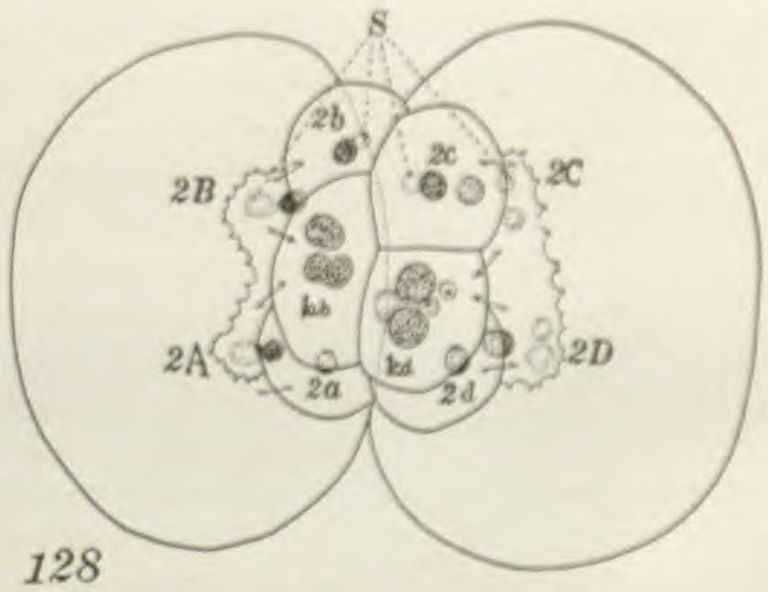

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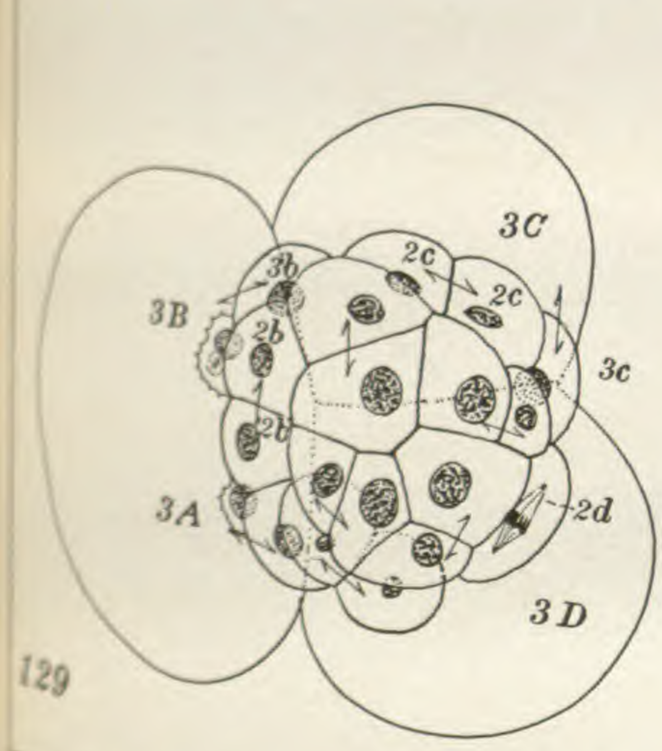

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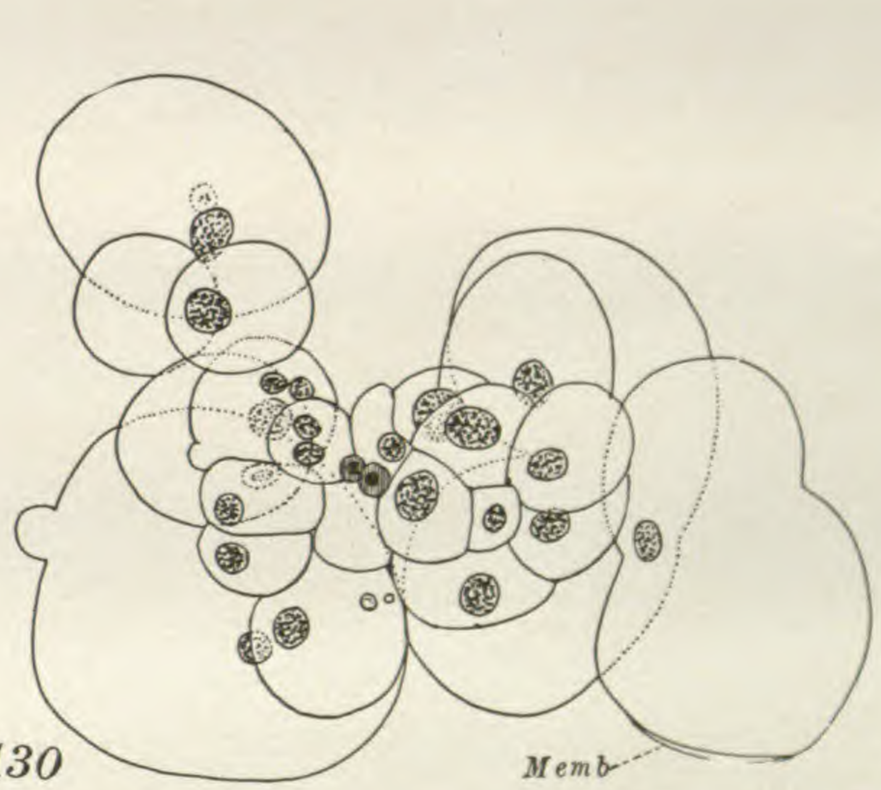

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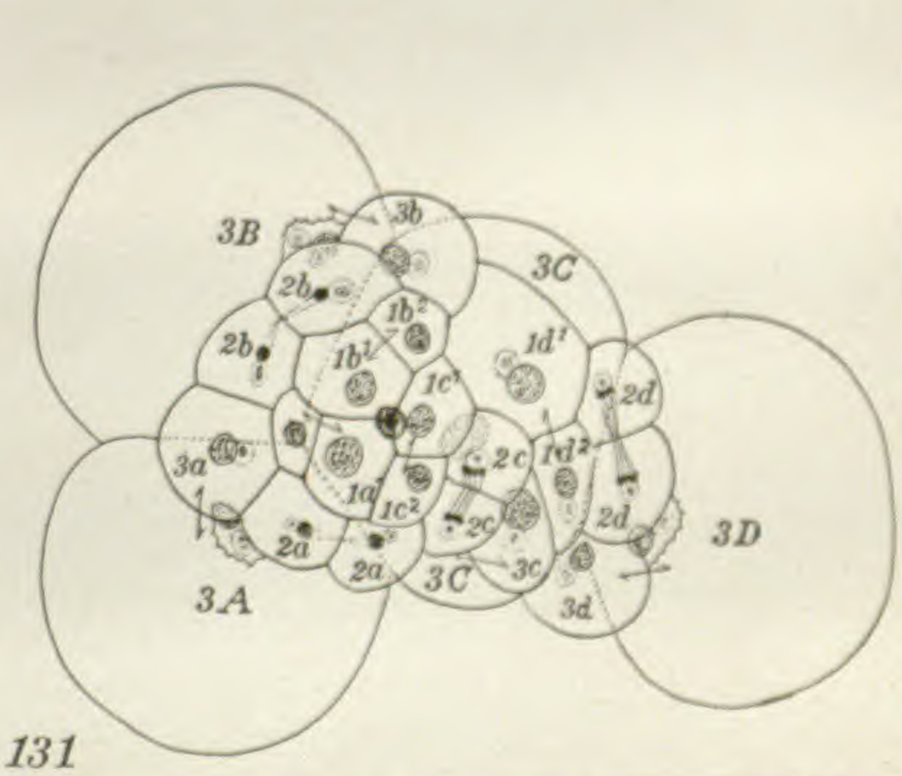

131

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CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

EFFECTS OF CARBONIC ACID

PLATE LIII.

Effects of Diluted Sea Water.

In figs. 132–135, 137–140, 144 the dilution was one part sea water to two parts fresh water; in all other cases the sea water was diluted with equal parts of fresh water. With higher dilutions the blastomeres tend to separate but do not swell appreciably.

Fig. 132. Exp. 875: Second polar spindle at animal pole; sperm nucleus has formed a spindle (♂*Sp*); the homogeneous chromatic sphere below this may represent an accessory sperm nucleus (♂*N*).

Fig. 133. Exp. 875: First cleavage spindle; the seven chromatic spheres may represent accessory sperm nuclei (♂*N*).

Fig. 134. Exp. 875: Enormous second polar body containing large nucleus and yolk; two nuclei and accessory sperm nucleus (♂*N*) in egg.

Fig. 135. Exp. 875: Probably ½ blastomere containing polyaster and with a micromere which has just divided.

Fig. 136. Exp. 872: Three blastomeres showing reversed polarity, the spheres, nuclei and cytoplasmic areas lying at the pole opposite the polar bodies; one sphere is found in each cell but in the two larger ones the nuclei are multiple.

Fig. 137. Exp. 875: Two macromeres, one containing a triaster, the other a tetraster; the two micromeres are normal except for their large size.

Fig. 138. Exp. 875: Similar to the preceding.

Fig. 139. Exp. 875: Side view of an egg similar to figs. 137, 138.

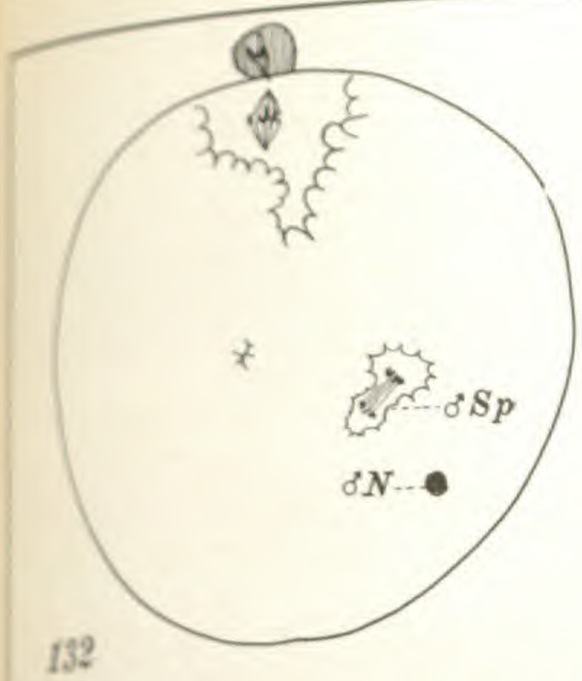
Fig. 140. Exp. 875: Macromeres *A* and *B* have not divided and the chromosomes are irregularly scattered in the spindle; macromeres *C* and *D* have divided normally giving rise to first and second micromeres and the first set are subdividing normally.

Fig. 141. Exp. 859: Chromosomes were scattered along the spindle during the third cleavage and have given rise to chromatic connections between daughter nuclei, which resemble amitoses.

Fig. 142. Exp. 872: The micromeres are larger than usual (two of them contain yolk) and they have caused a separation of *A*, *B*, from *C*, *D*.

Fig. 143. Exp. 872: The micromeres are larger than usual and contain yolk; the macromeres are separated and one which has just divided (*Y*, *Y*) contains yolk but no cytoplasmic areas; the chromosomes are here scattered along the spindle axis, thus forming a chromatic connection.

Fig. 144. Exp. 875: ⅔ blastomeres, each of which has given rise to one micromere, which has subdivided; the macromeres contain spindles along which the chromosomes are scattered irregularly.



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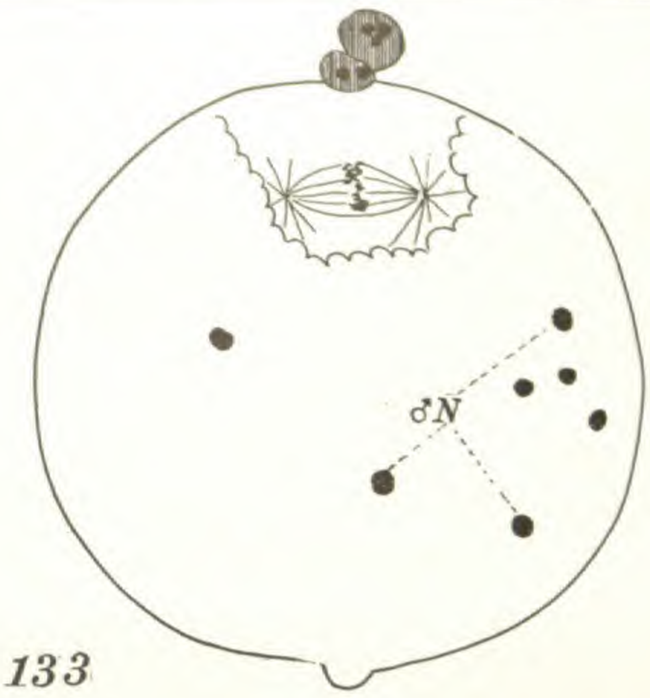

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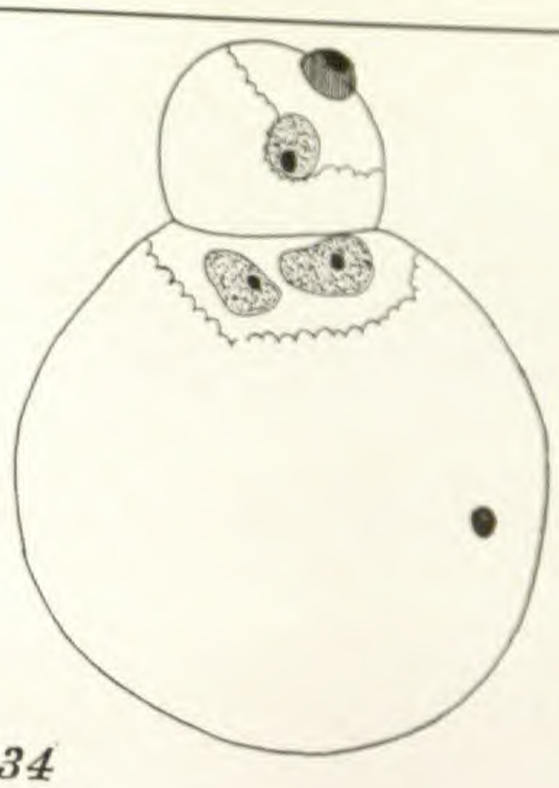

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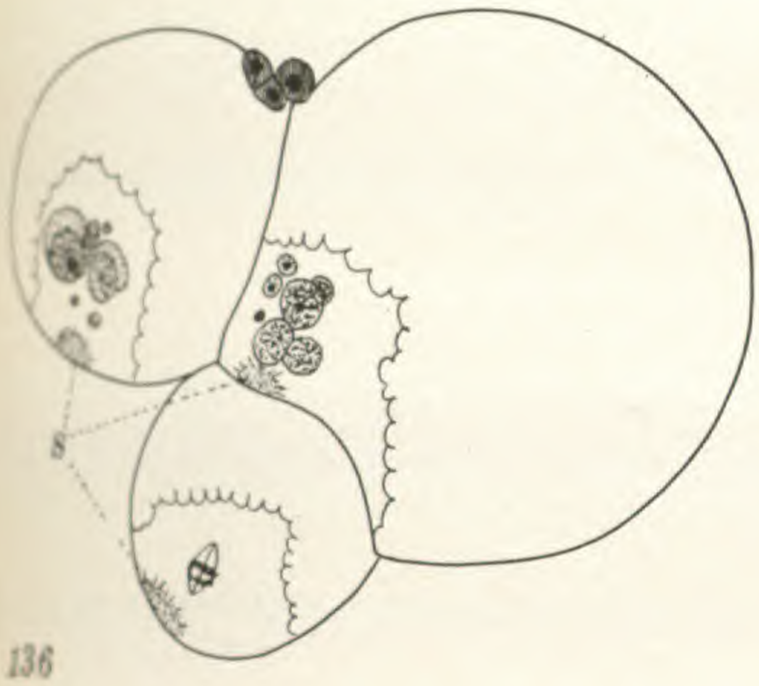

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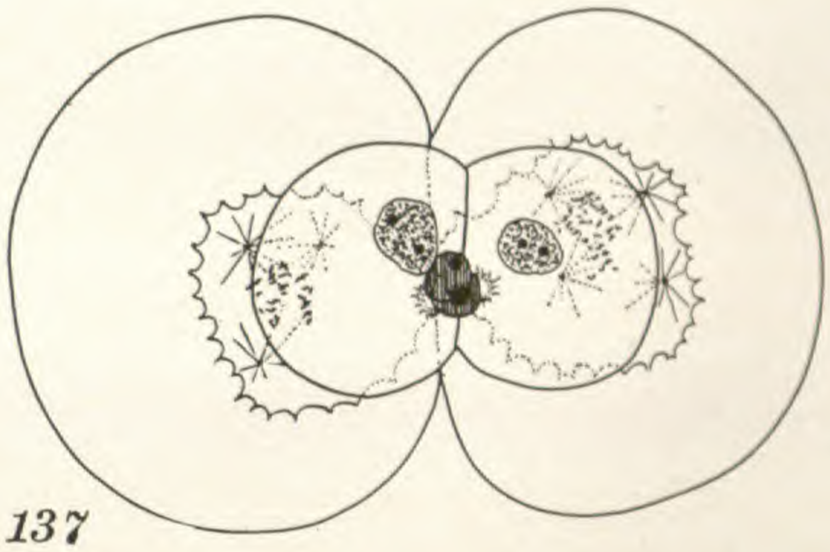

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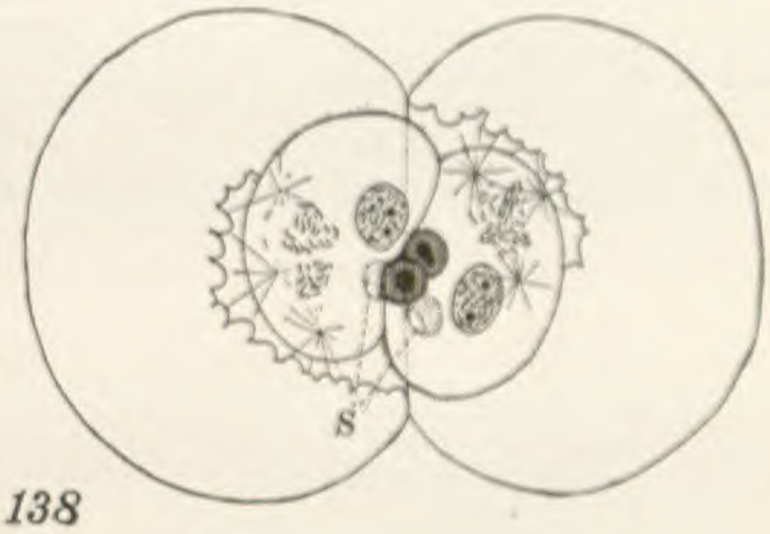

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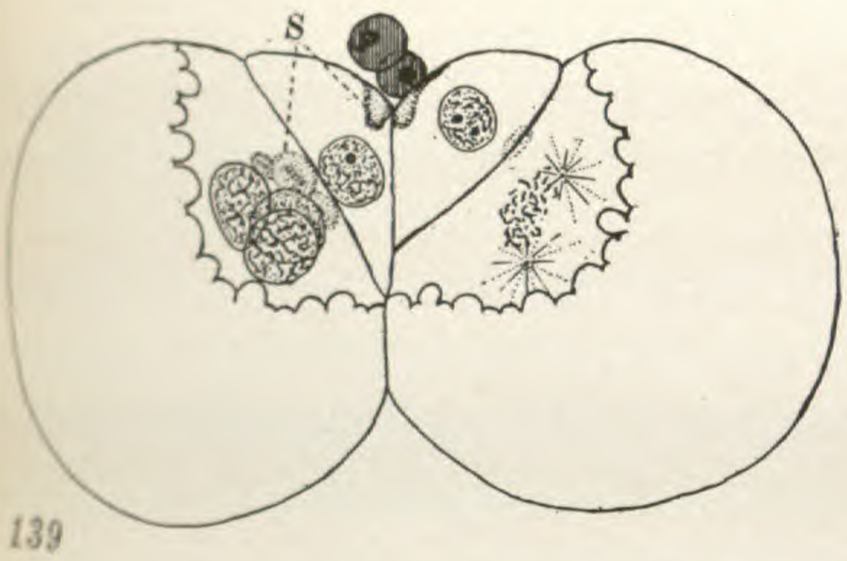

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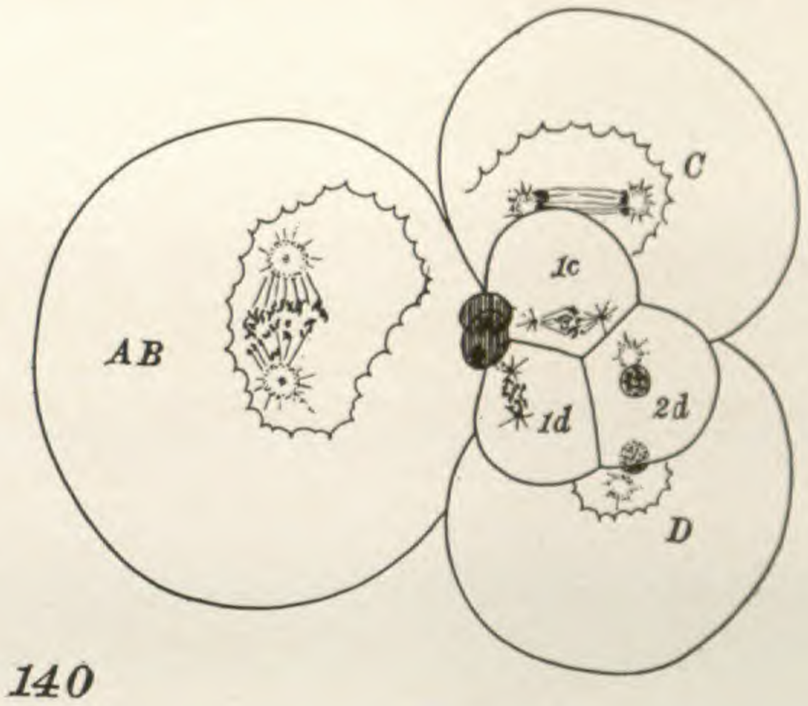

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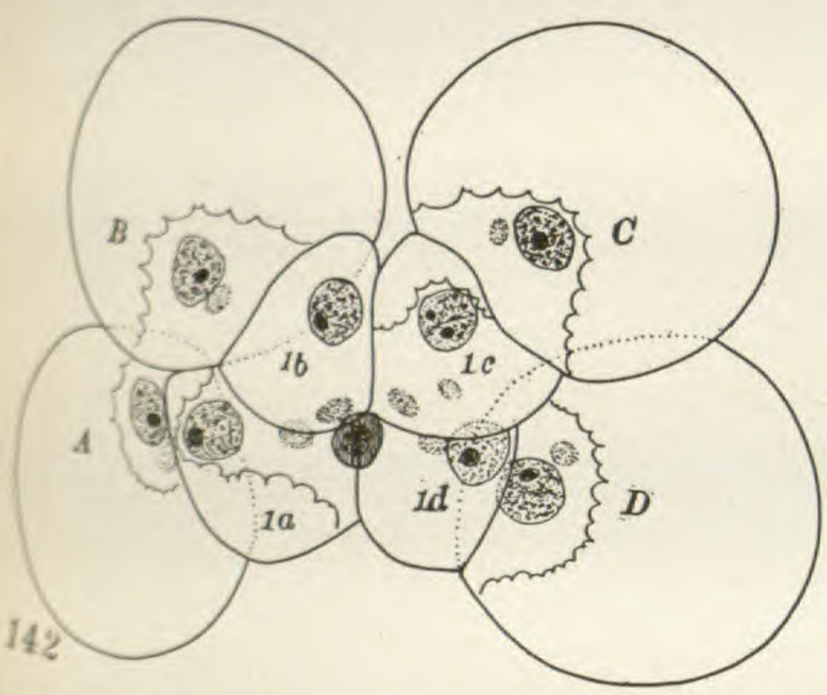

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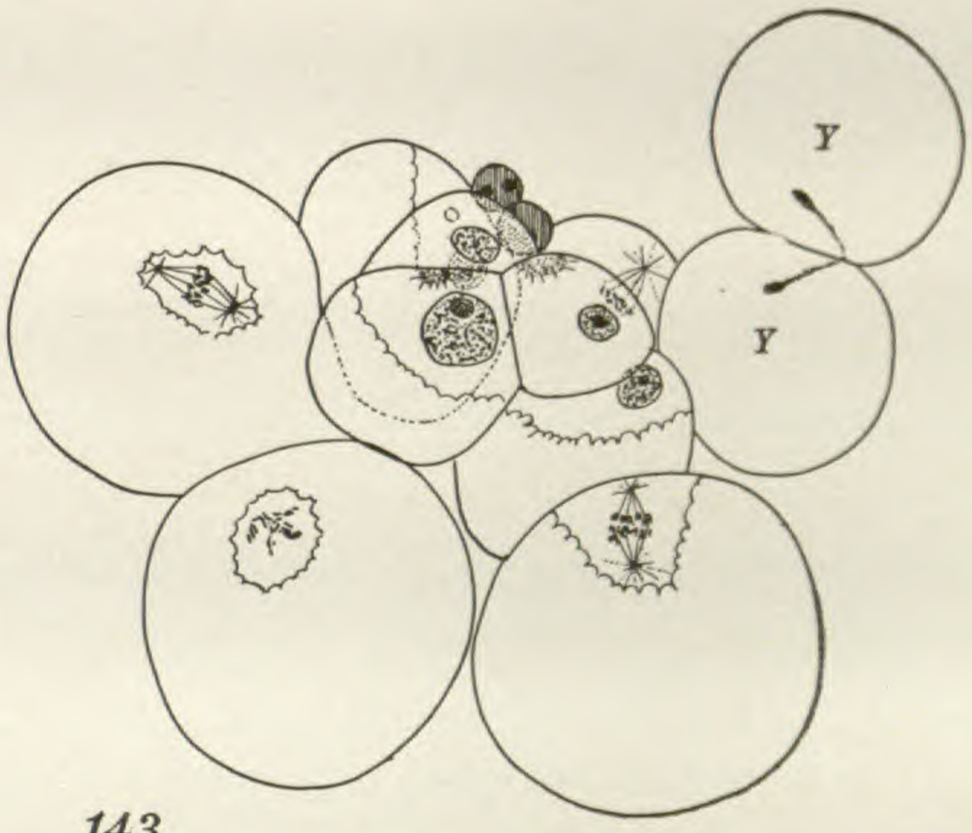

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CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

DILUTED SEA WATER

PLATE LIV.

Effects of Diluted Sea Water.

In all experiments represented on this plate sea water was diluted with equal parts of distilled water

Fig. 145. Exp. 858: Several micromeres have been formed but the yolk has not divided; three of the cells contain several nuclei and spheres, the result probably of polyasters, and one contains a tetraster.

Fig. 146. Exp. 993 (1): Similar to the preceding; the protoplasmic micromeres are partly constricted from the yolk.

Fig. 147. Exp. 858: Exogastrula; similar to the preceding but of a more advanced stage; the multinucleate yolk cell is uncovered by the ectoderm.

Fig. 148. Exp. 993: Similar to the preceding.

Fig. 149. Exp. 993: Side view of an egg placed in diluted sea water in the 2-cell stage; the second cleavage of the yolk was suppressed, but several micromeres have been formed from each macromere.

Fig. 150. Exp. 956: Egg similar to the preceding, viewed from the animal pole; each macromere contains a large quadripartite nucleus and has given rise to twelve micromeres, which cannot be individually identified.

Fig. 151. Exp. 993: Isolated $\frac{1}{2}$ blastomere, the yolk cell has not divided, but contains several nuclei and has given rise to nine micromeres.

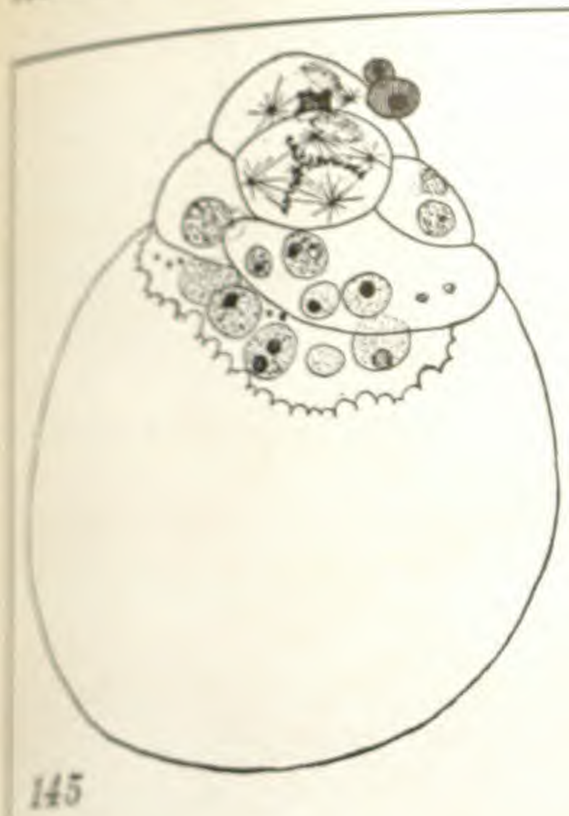
Figs. 152, 153. Exp. 858: Top and side views of eggs which were placed in diluted sea water after formation of the 1st set of micromeres; several dividing cells contain triasters or tetrasters and the chromosomes are widely scattered; chromatic connections between daughter nuclei are falsely suggestive of amitosis.

Fig. 154. Exp. 858: Side view of egg placed in diluted sea water after formation of the three sets of micromeres which are approximately normal; scattered chromosomes have given rise to chromatic connections between daughter nuclei.

Fig. 155. Exp. 993: Isolated $\frac{2}{4}$ blastomeres which have produced a $\frac{2}{4}$ micromere plate; the macromere 4*D* has given off the mesentoblast 4*d* which is now dividing in normal manner.

Fig. 156. Exp. 871: The 1st set of micromeres have divided twice in normal directions, as indicated by the arrows, giving rise to twelve micromeres; in the formation of the 2d set of micromeres the division of the macromeres was approximately equal.

Figs. 157, 158. Exp. 858: Eggs in which the nuclear division at the 2d cleavage took place normally, but in which the cell body did not divide; three quartets of micromeres were formed and have subdivided in approximately normal manner, although there are only two separate macromeres. The 4th quartet cells 4*d* and 4*c* form simultaneously from the undivided macromere *CD*, though in normal eggs 4*d* (the mesentoblast) forms at the 24-cell stage, while 4*c* (an entoblast) does not form until the 52-cell stage.



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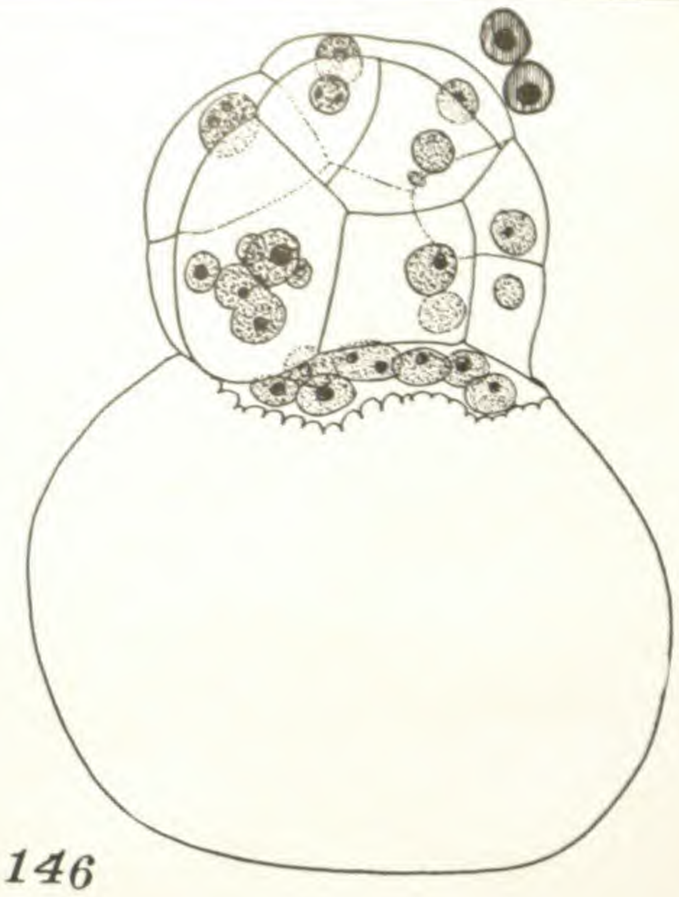

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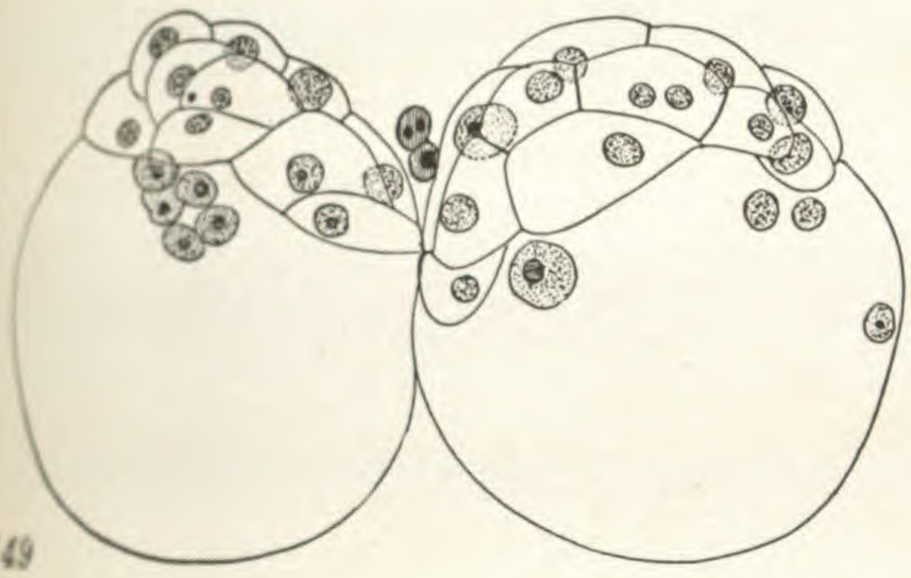

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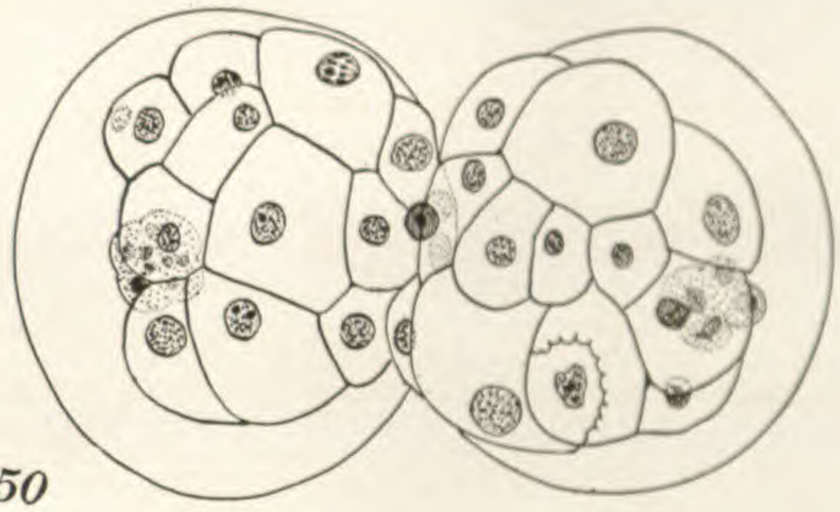

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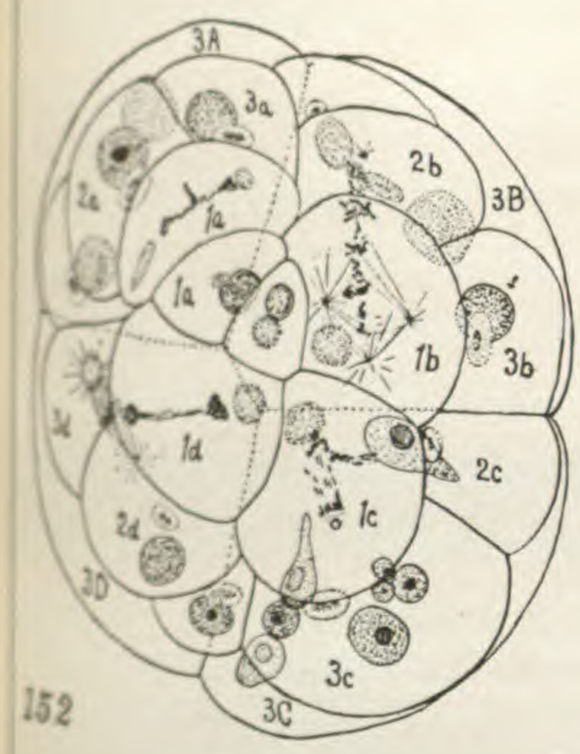

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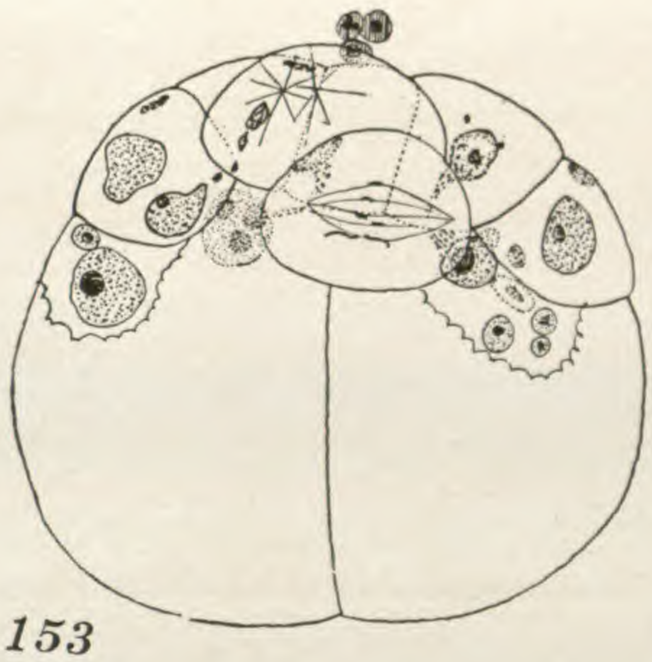

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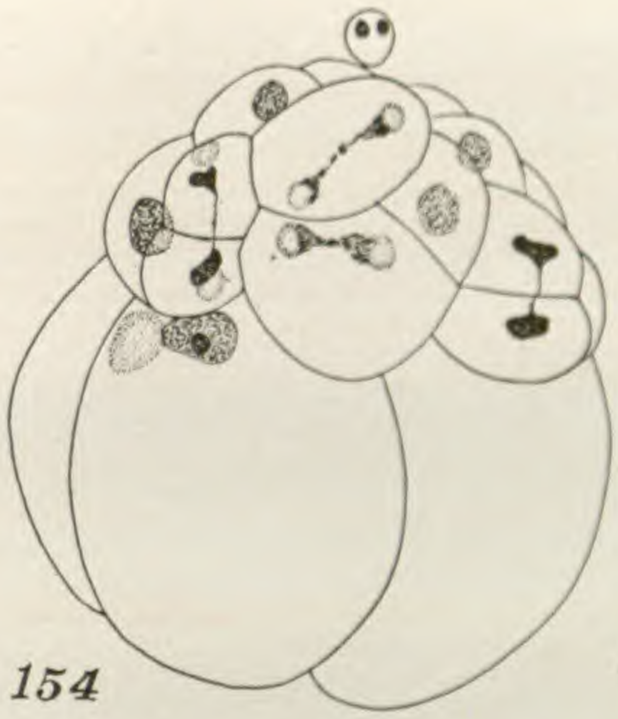

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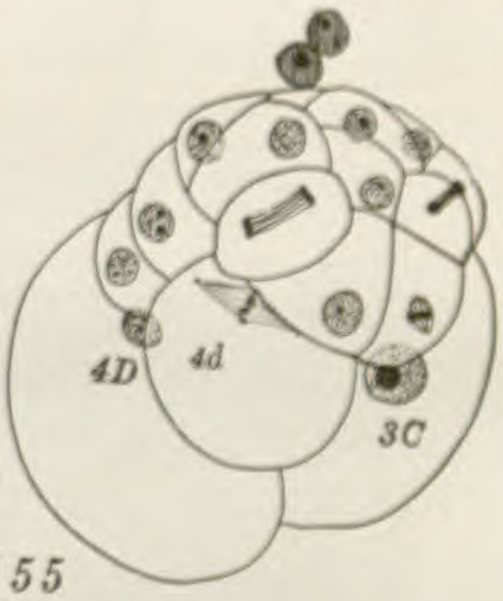

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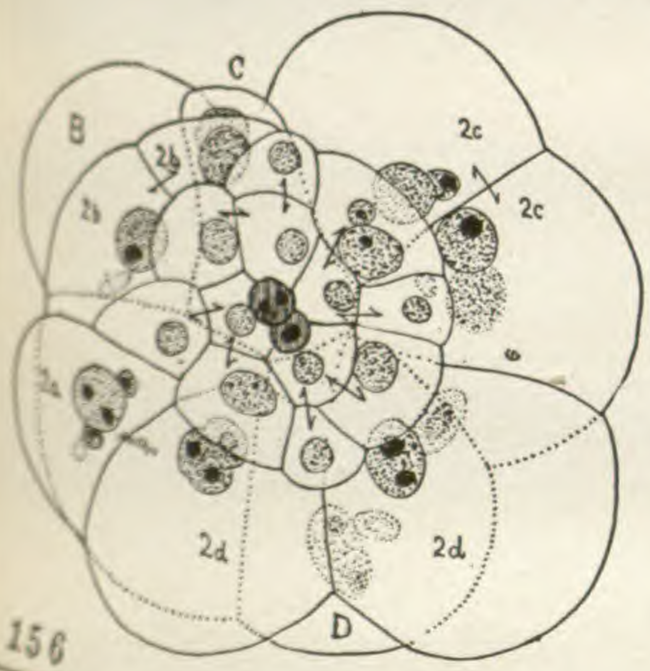

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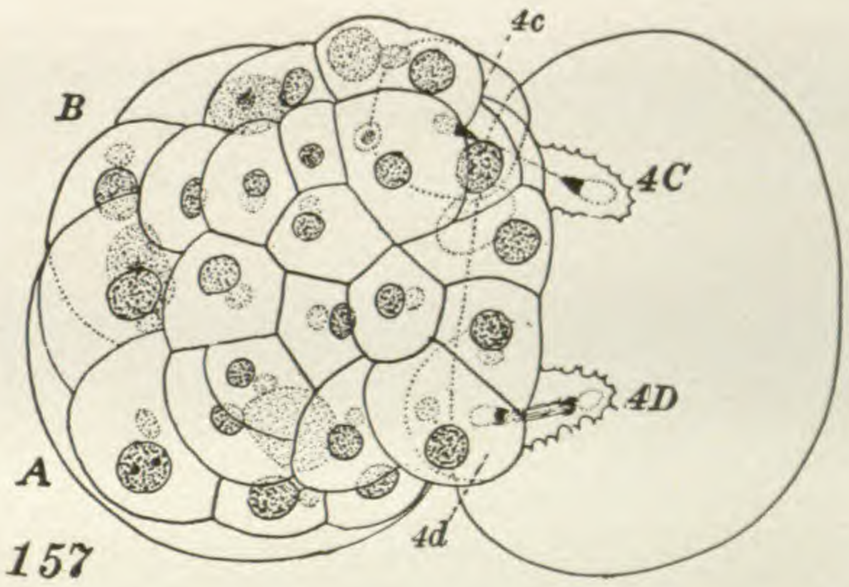

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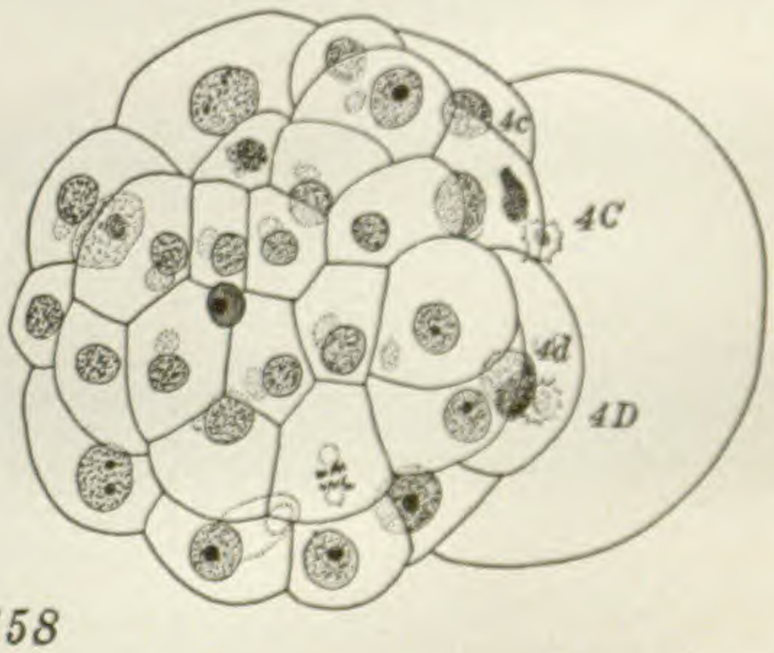

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CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

DILUTED SEA WATER

PLATE LV.

Effects of Hypertonic Sea Water.

All eggs shown on this plate are from Exp. 804, and were subjected to 1 per cent. NaCl in sea water for 4 hrs.

Figs. 159–163. The sperm nucleus lies in a small area of cytoplasm near the lower pole; the egg nucleus lies in a larger area of cytoplasm at the animal pole; various stages in the formation of the egg spindle are shown.

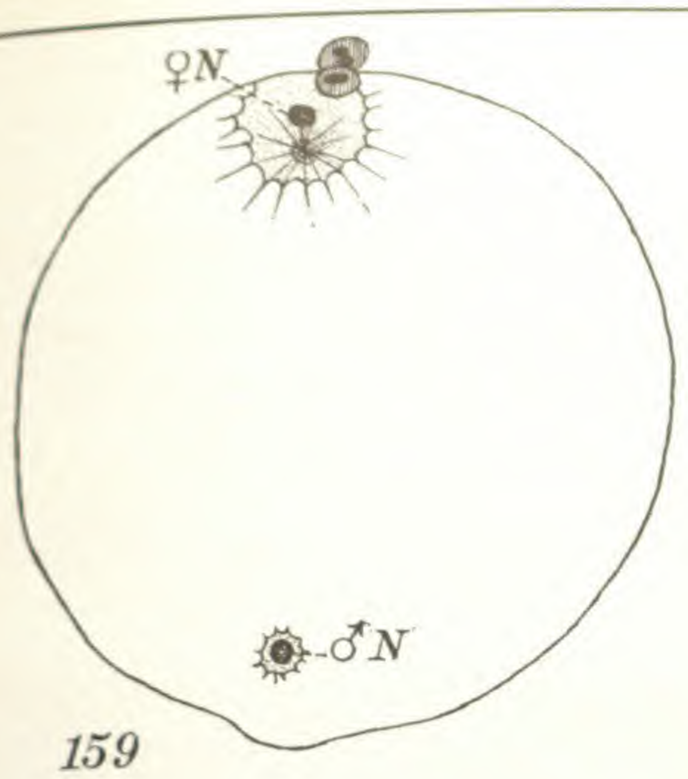
Fig. 164. Two spindles, probably those of egg and sperm, are joined at one pole.

Figs. 165, 166. Tetrasters, probably formed from the egg and the sperm spindles.

Fig. 167. Two spindles, probably those of the egg and the sperm, joined at one pole.

Fig. 168. Two spindles, probably those of the egg and sperm, quite separate.

Figs. 169, 170. Tetrasters in different phases of the separation of the chromosomes.



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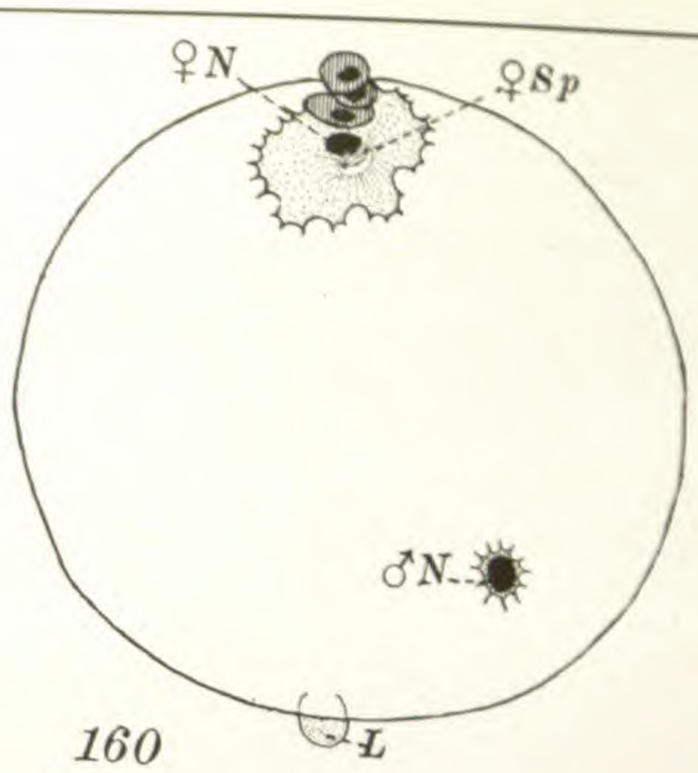

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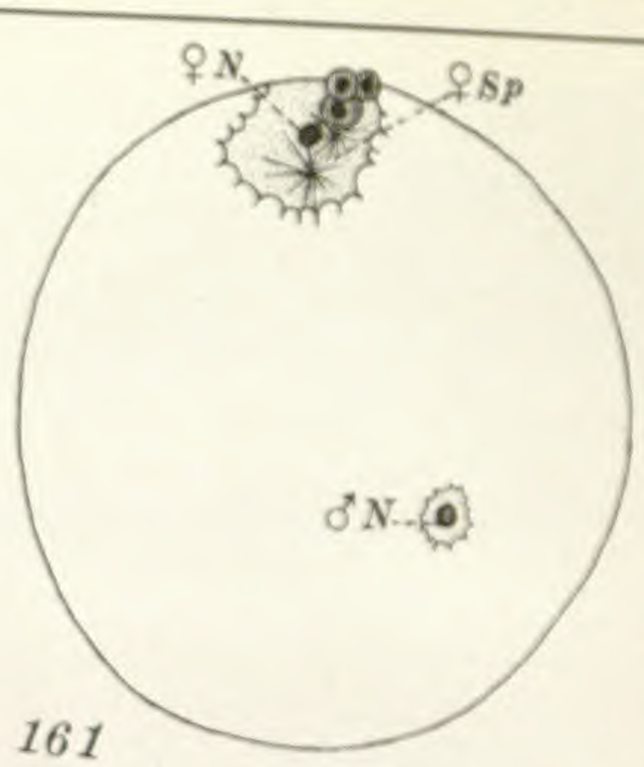

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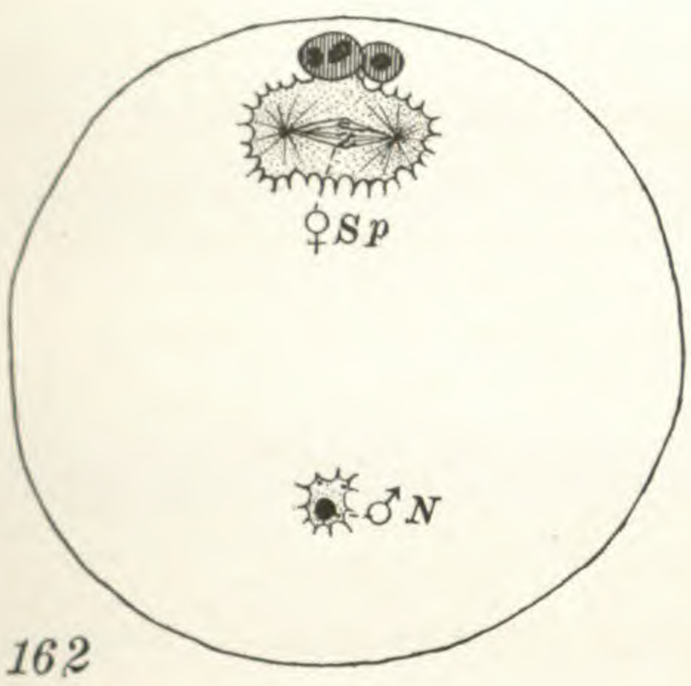

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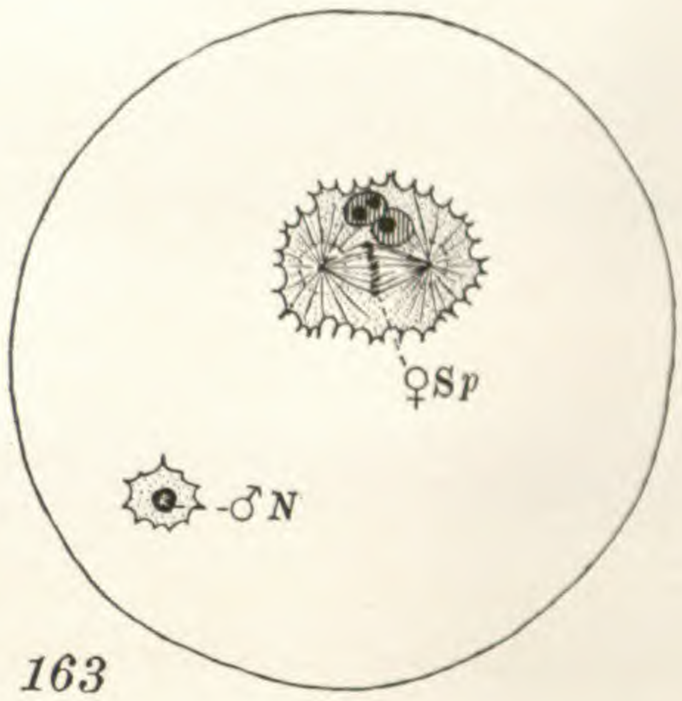

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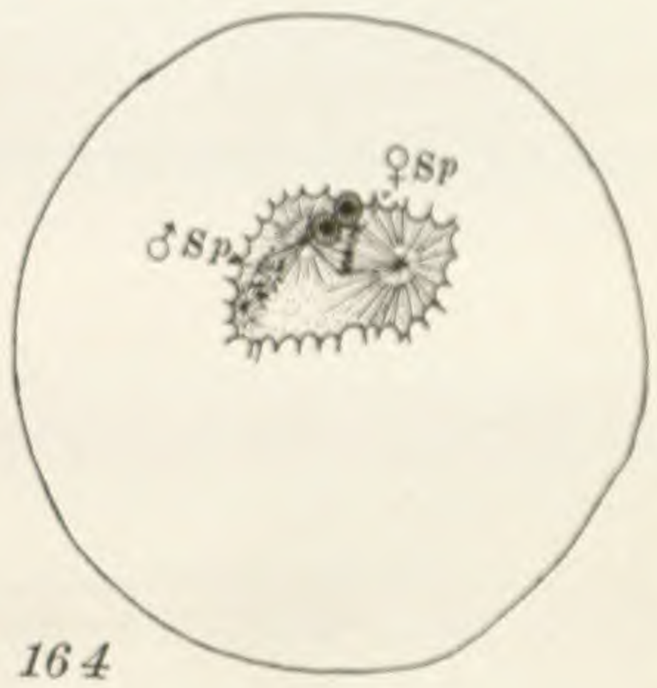

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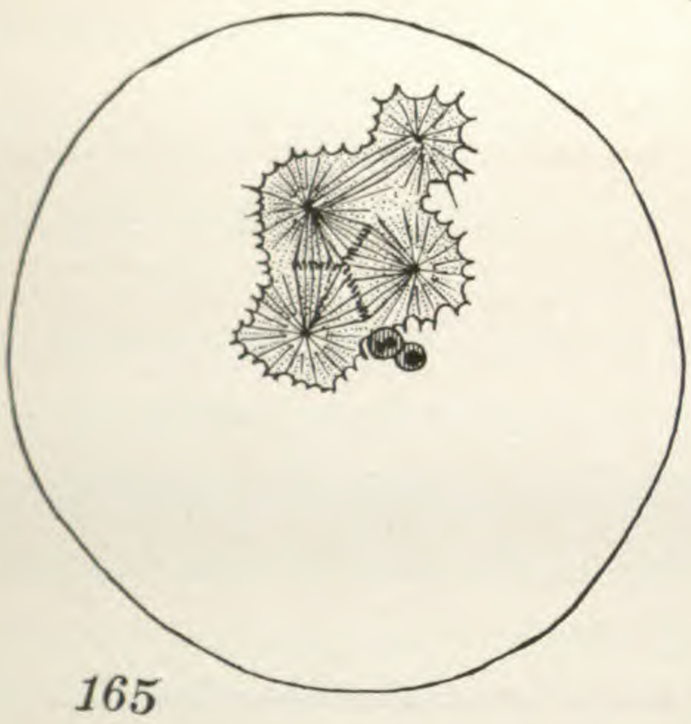

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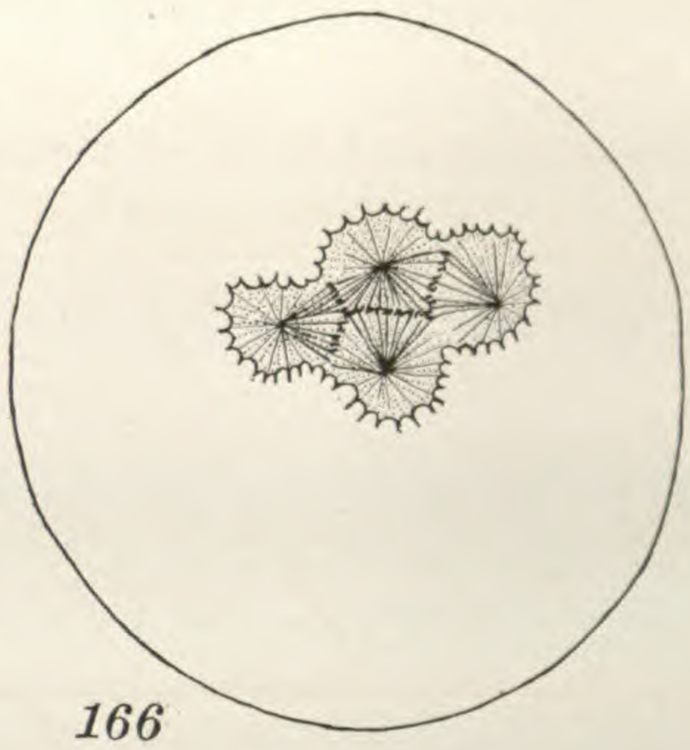

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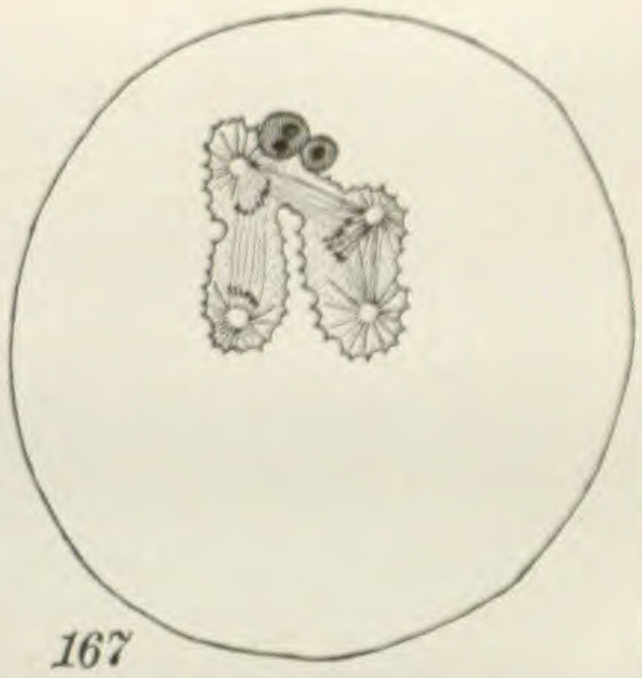

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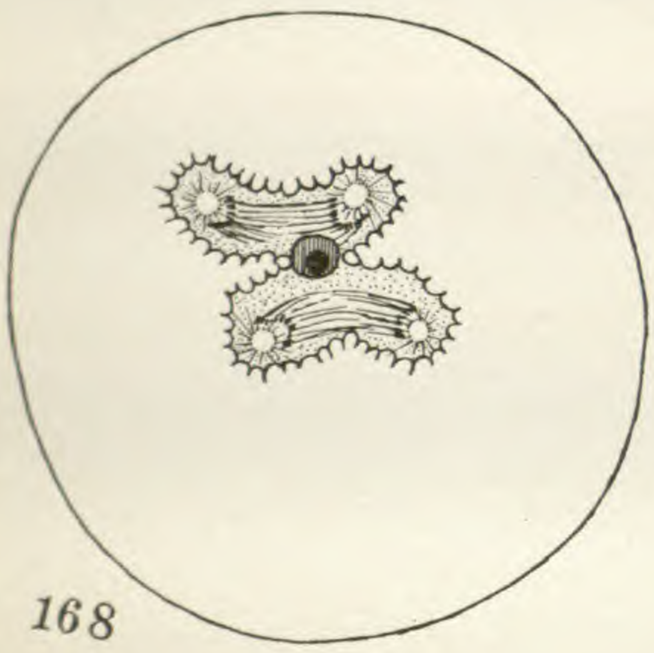

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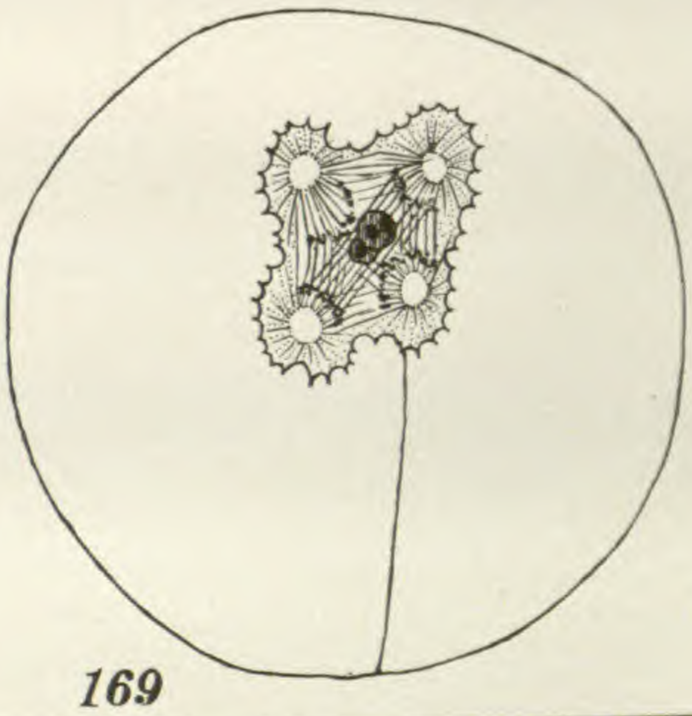

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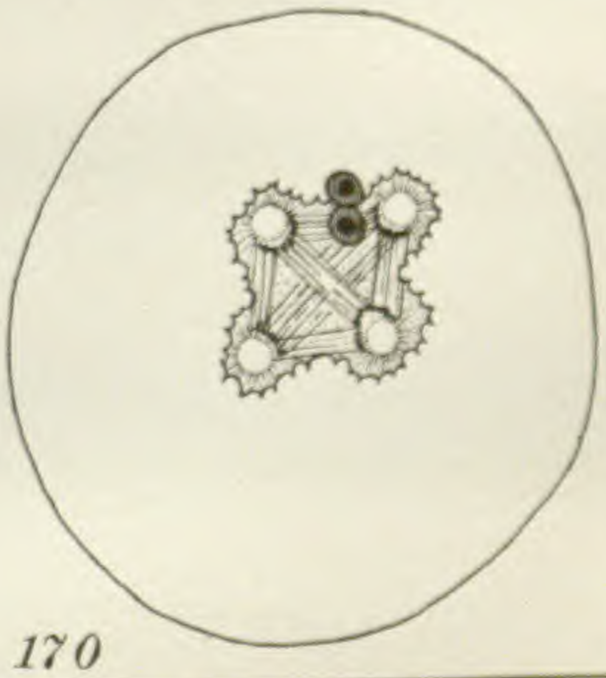

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CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

HYPERTONIC SEA WATER

PLATE LVI.

Effects of Hypertonic Sea Water.

Fig. 171. Exp. 823: 3 per cent. NaCl, 16 hrs., normal 8 hrs. Egg nucleus very small and clear with chromosomes persistent within vesicle and egg centrosome outside vesicle; the sperm nucleus is enormous and contains much chromatic sap.

Fig. 172. Exp. 823: Similar to the preceding.

Fig. 173. Exp. 837: 1 per cent. KCl, 9 hrs., normal 35 hrs. Development has been stopped but the egg is not dead; the germ nuclei are very large and achromatic; small achromatic spherules lie in the cytoplasm.

Fig. 174. Exp. 822: 2 per cent. NaCl, 16 hrs., normal 8 hrs. Achromatin in large and small vesicles in the cytoplasm; germ nuclei normal.

Fig. 175. Exp. 822: The germ nuclei are broken up into many separate vesicles, each with a chromatic nucleolus.

Fig. 176. Exp. 823: Two-cell stage from same experiment as figs. 171, 172; nuclei very large and achromatic.

Fig. 177. Exp. 822: Side view of egg in 2-cell stage, each cell containing a large sphere (*S*) and one or more chromatic and two or three achromatic nuclear vesicles.

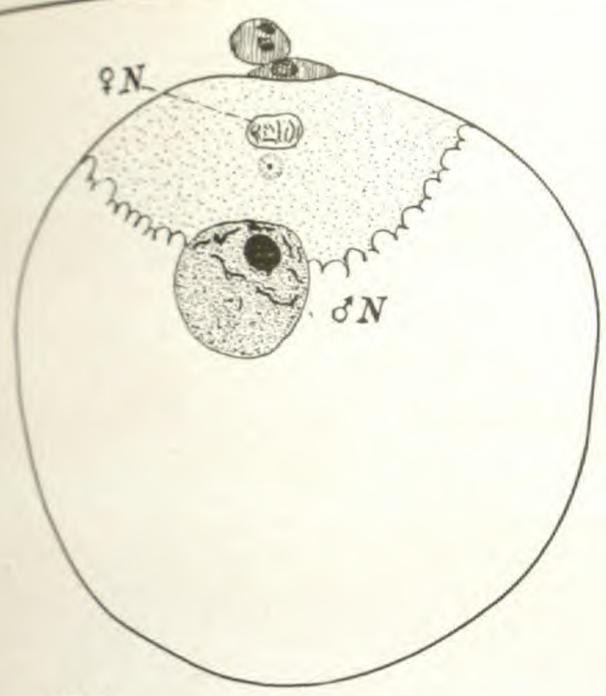
Fig. 178, 179. Exp. 810: 3 per cent. NaCl, 15 hrs.: Side views of egg in 2-cell stage showing the chromatin massed within the nuclear vesicle; the latter are elongated along the line of the former spindle axis.

Figs. 180–182. Same experiment as preceding; 4-cell stages from animal pole.

Fig. 180. In one half of egg the remains of the 2d cleavage spindle are still visible and the chromatin has formed no nuclear vesicle; in the other half the nuclear vesicles are elongated along the line of the spindle axis, the chromatin being massed at the ends of the vesicle nearest the spheres.

Fig. 181. Nuclear vesicles elongated along the spindle axis are present in three of the cells, and in each the chromatin is massed at the end of the vesicle nearest the sphere; in the fourth cell no nuclear vesicle is present, but traces of spindle fibres may be seen.

Fig. 182. In all four cells the nuclear vesicles are rounded and the chromatin is massed near the center of each vesicle.



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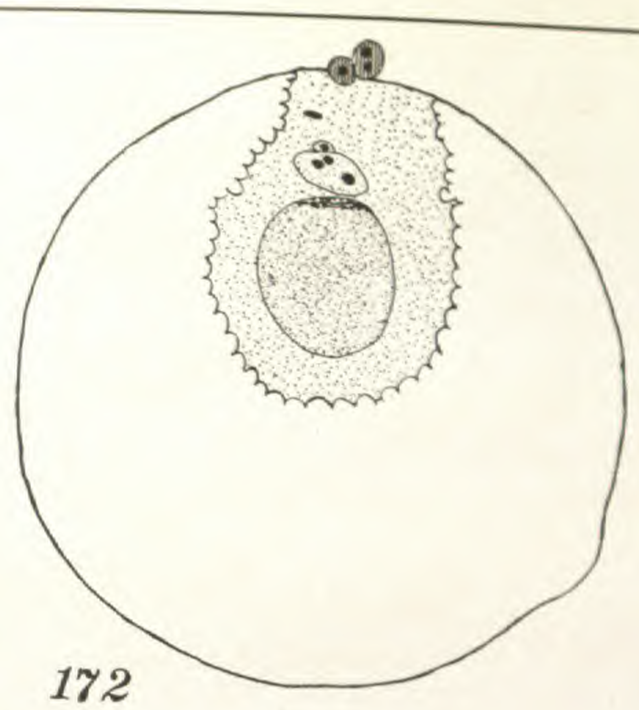

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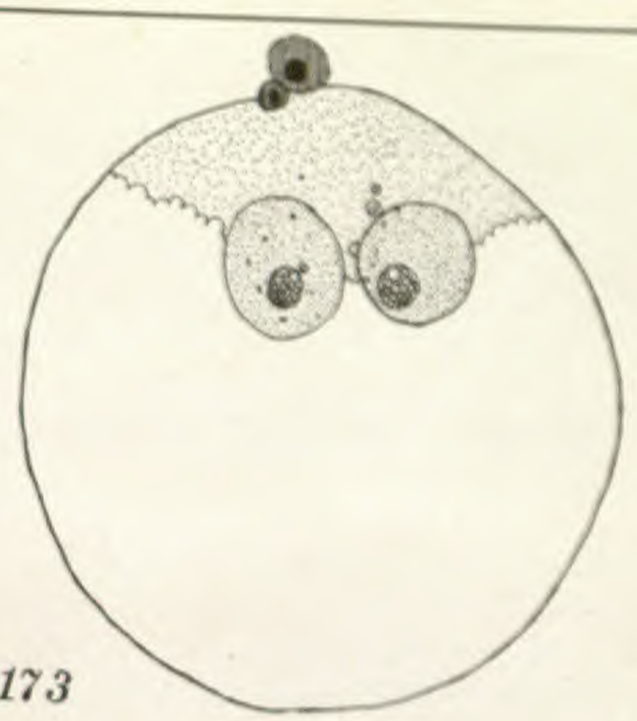

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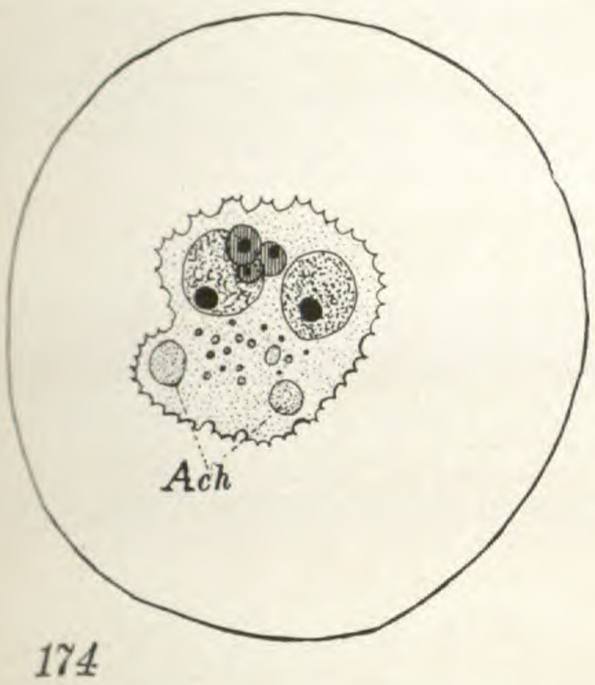

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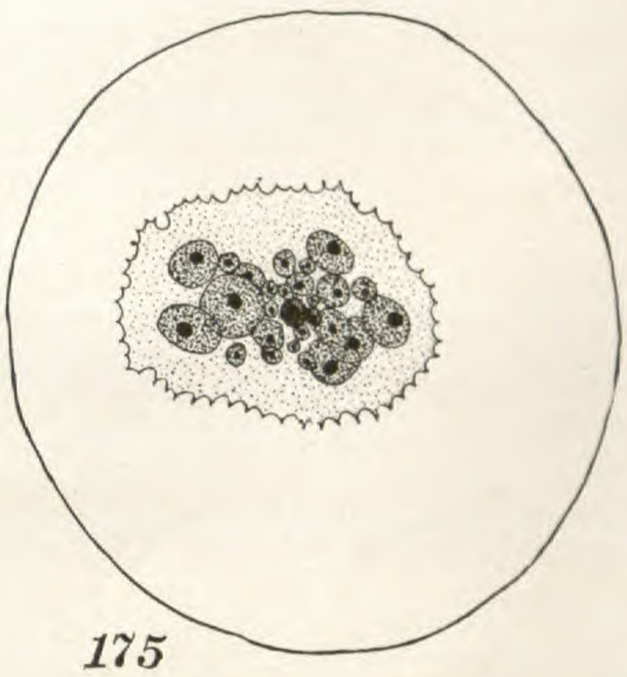

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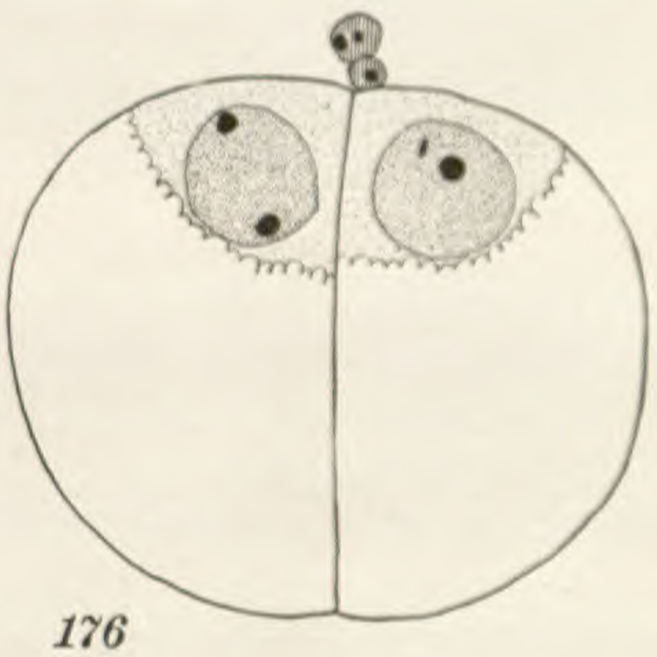

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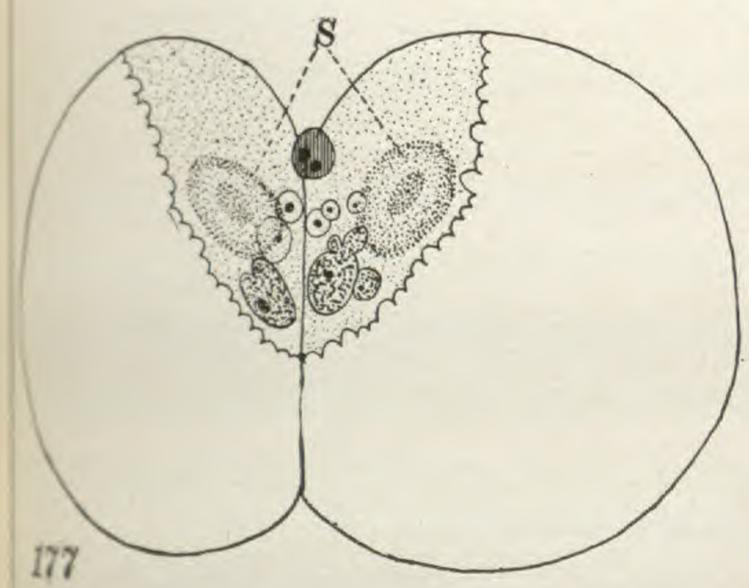

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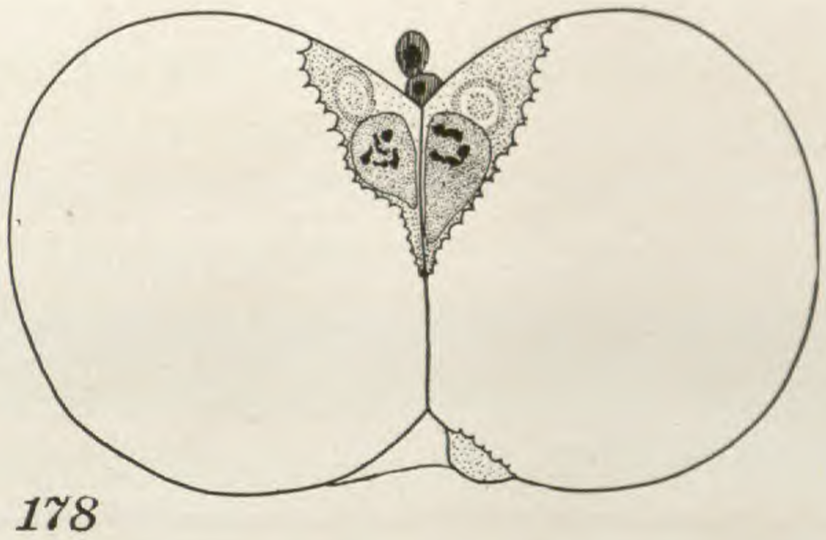

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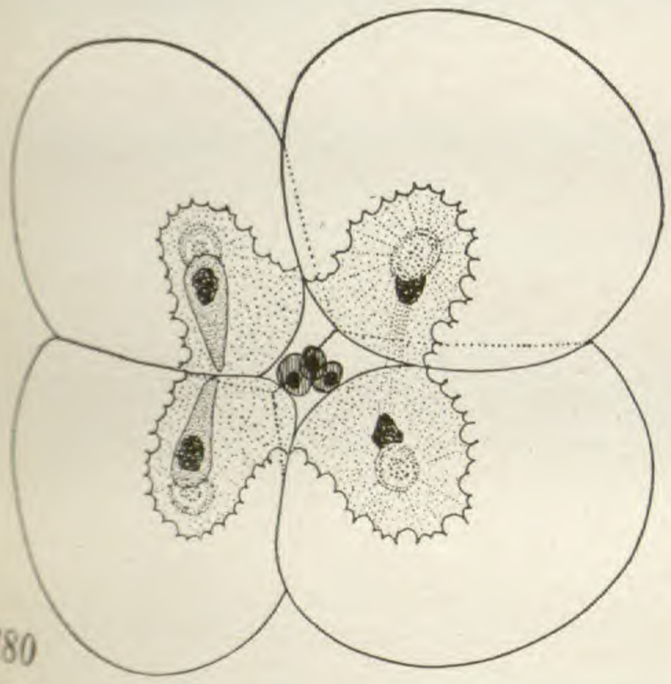

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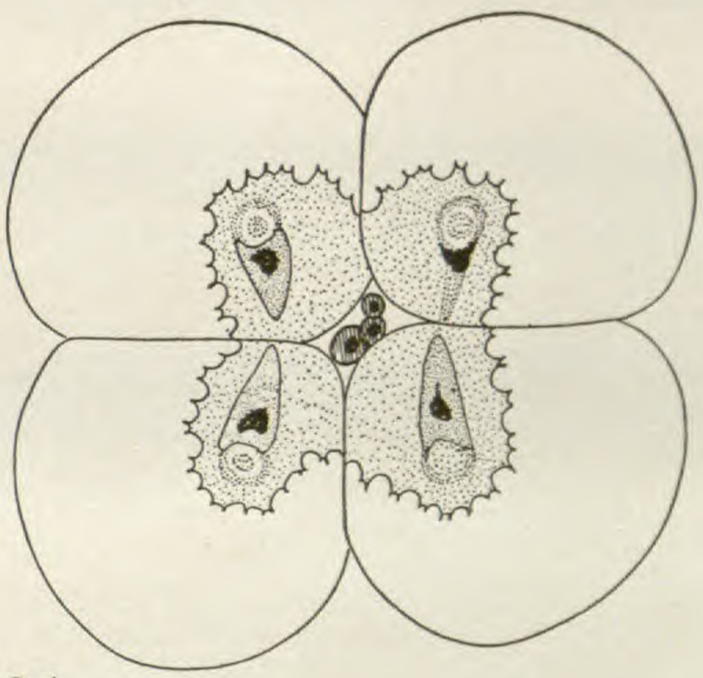

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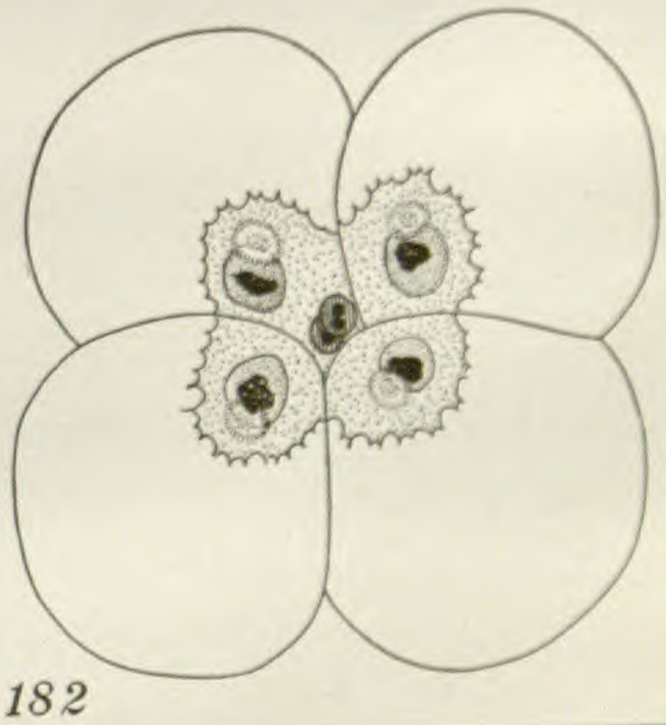

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Conklin del.

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

HYPERTONIC SEA WATER

PLATE LVII.

Effects of Hypertonic Sea Water.

Figs. 183–185 were in 1-cell stage at beginning of experiment; Figs. 186–196 were in 2-cell stage.

Fig. 183. Exp. 805: 2 per cent. NaCl, 4 hrs.; in both egg and sperm nuclei the chromatin is aggregated into a dense mass in the center of the nuclear vesicle; there are many cytasters near the sperm nucleus.

Fig. 184. Exp. 809: 2 per cent. NaCl, 15 hrs.; the chromatic and achromatic parts of the germ nuclei are in separate vesicles.

Fig. 185. Exp. 809: Similar to the preceding; a double cytaster is present near the germ nucleus.

Fig. 186. Exp. 809: 2 per cent. NaCl, 15 hrs.; the chromatic and achromatic parts of the nucleus are in separate vesicles; the achromatic vesicles are numerous and scattered.

Fig. 187. Exp. 809: Side view of egg similar to preceding.

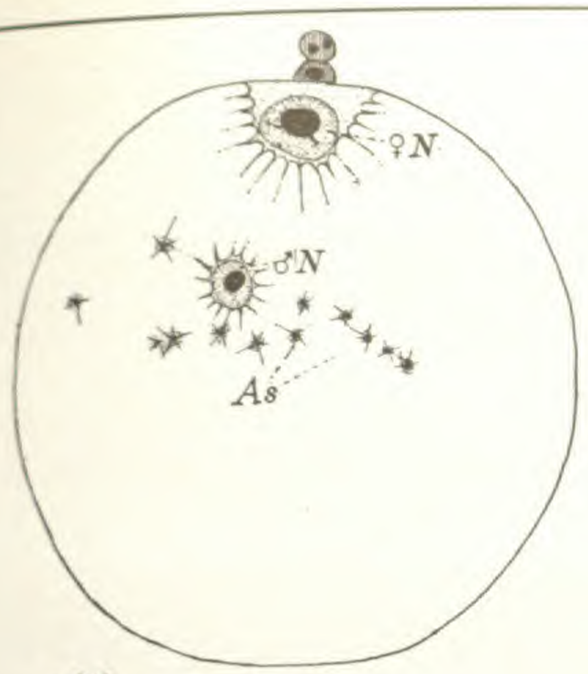
Fig. 188. Exp. 809: Egg similar to the preceding showing two principal achromatic vesicles (*Ach*) and many smaller vesicles or sphere granules.

Figs. 189, 190. Exp. 805: 2 per cent. NaCl, 4 hrs.; the 2d cleavage spindles are much shrunken in size; the archiplasm around them is much condensed while many small radiating masses of archiplasm are left along the astral radiations as cytasters.

Figs. 191, 192. Exp. 823: 3 per cent. NaCl, 16 hrs., normal 8 hrs.; top and side views of eggs showing in addition to the principal masses of chromatin (*Ch*) very numerous granules or spherules which probably represent scattered achromatic material (*Ach*).

Figs. 193, 194. Exp. 837: 1 per cent. KCl, 9 hrs., normal 36 hrs.; the numerous karyomeres have begun to absorb achromatin and to fuse together.

Figs. 195, 196. Exp. 808: 1 per cent. NaCl, 15 hrs.; top and side views of eggs with two macromeres and two micromeres, each with many masses of chromatin (karyomeres) and several spheres or asters.



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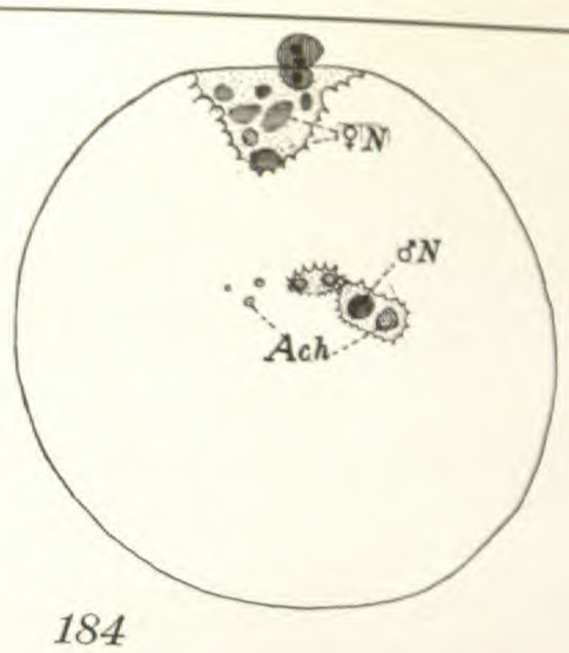

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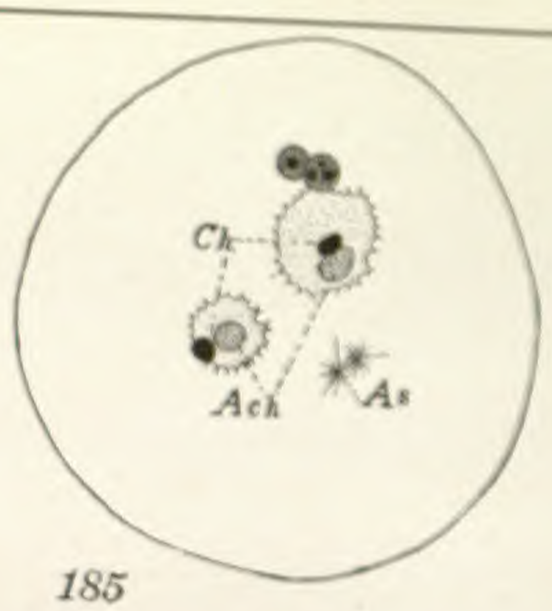

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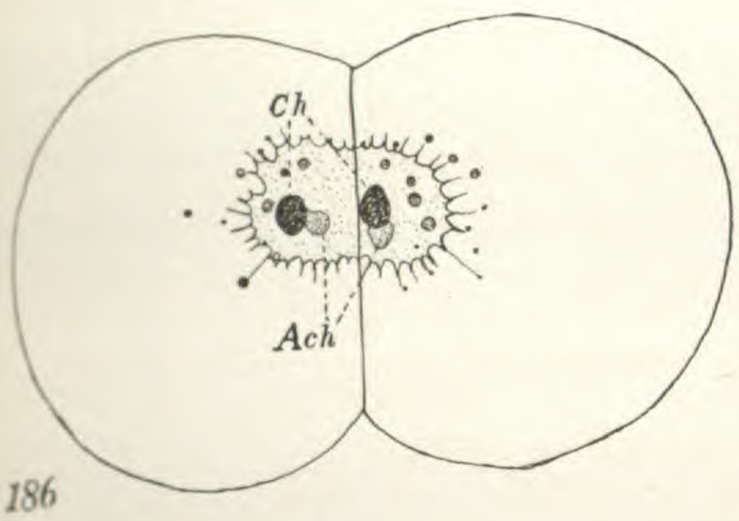

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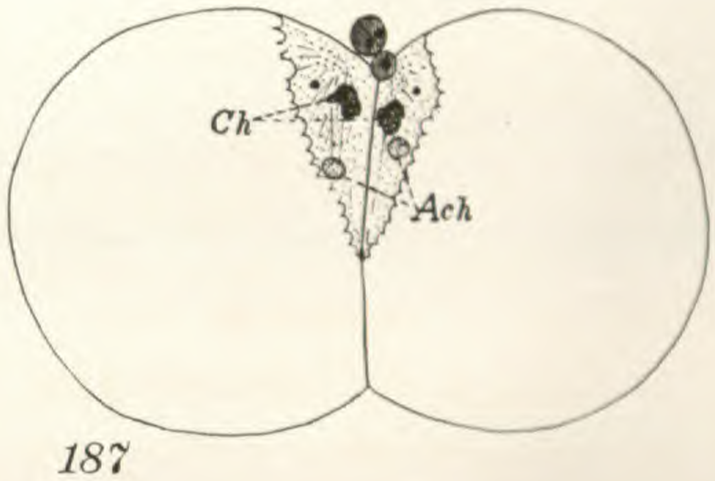

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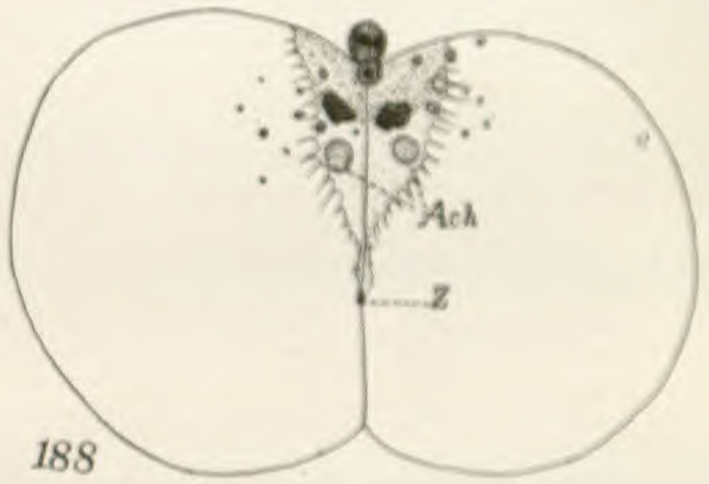

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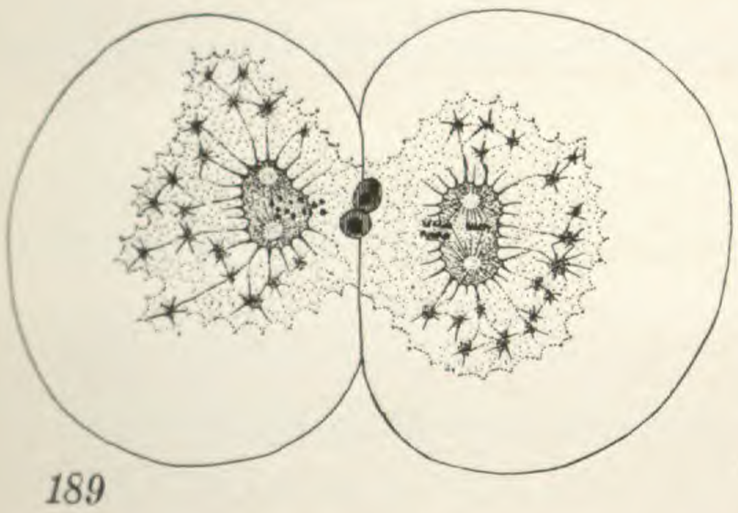

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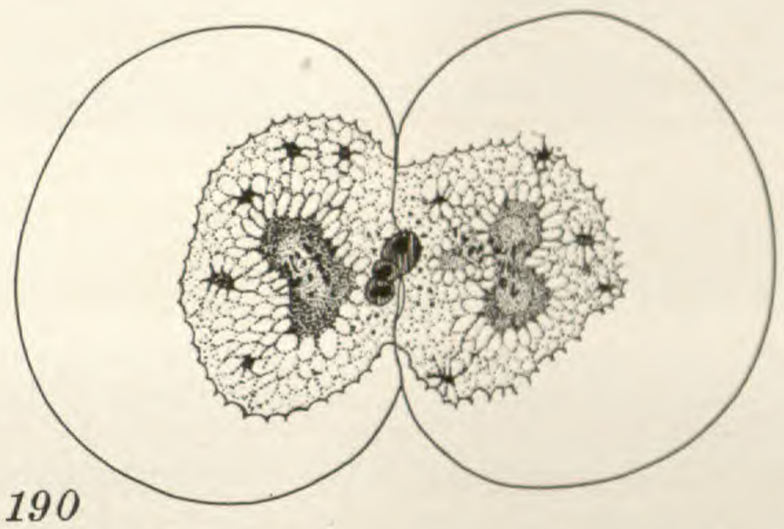

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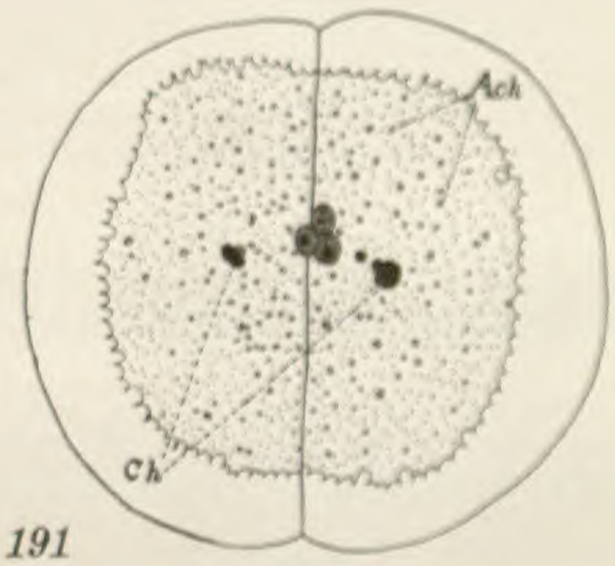

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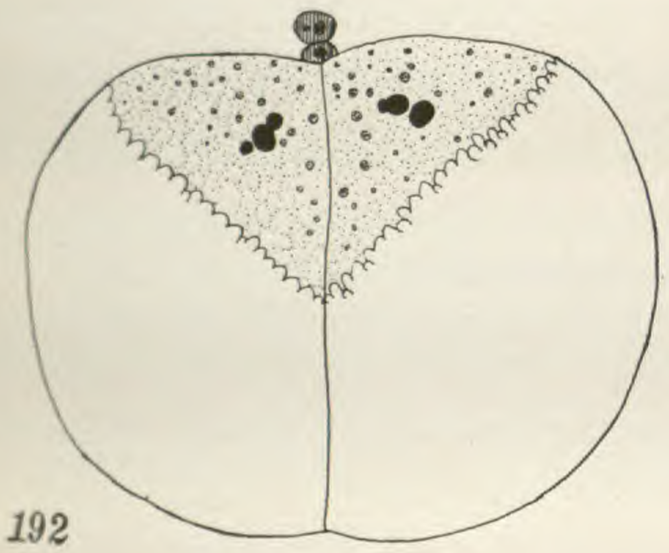

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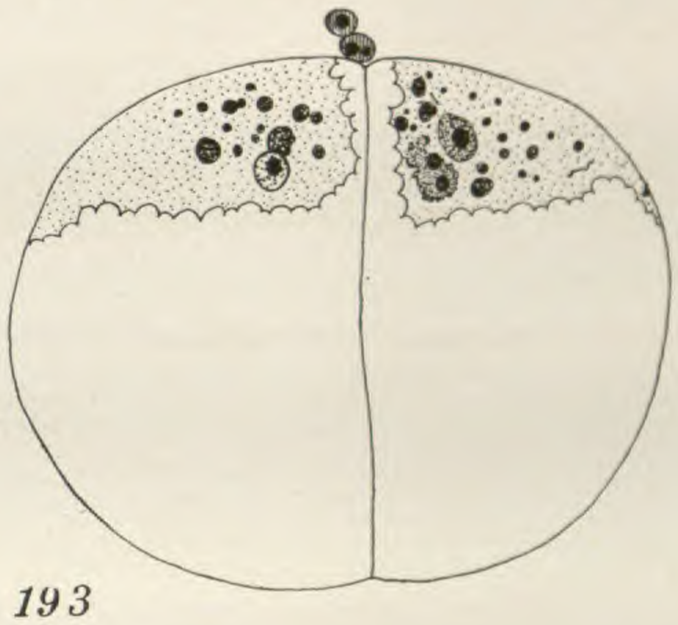

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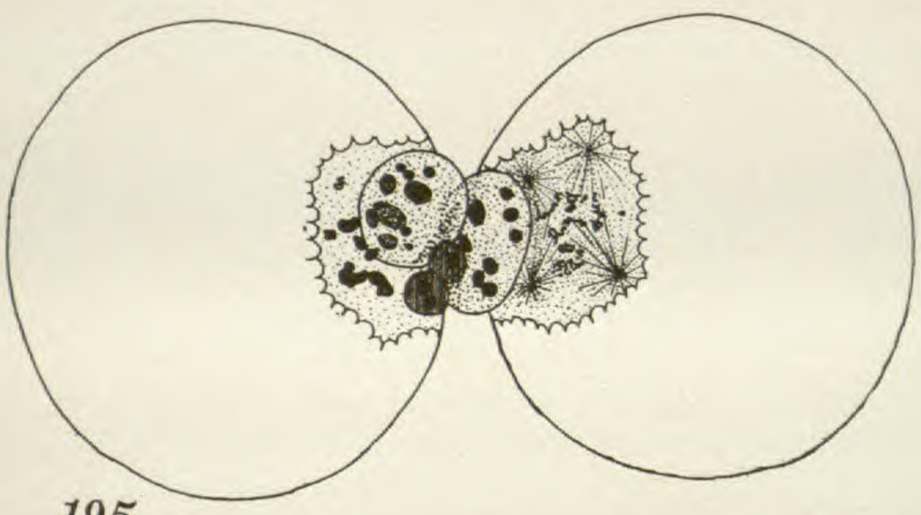

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Conklin del.

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

HYPERTONIC SEA WATER

PLATE LVIII.

Effects of Hypertonic Sea Water.

All eggs represented on this plate were put into hypertonic solutions in the 1-cell stage, and with the exception of fig. 197 none of them show division of the yolk.

Fig. 197. Exp. 842: 4 per cent. $MgCl_2$, 5 hrs., normal 17 hrs.; the two cells at the upper pole are probably enormous polar bodies, both of which contain mitotic figures.

Fig. 198. Exp. 991: 1 per cent. $MgCl_2$, 18 hrs.; one large cell (macromere) contains all the yolk, two smaller cells (micromeres) are purely protoplasmic; both macromeres and micromeres contain many nuclei (karyomeres), the chromatin of each being condensed into one or two masses.

Fig. 199. Exp. 834: 3 per cent. $MgCl_2$, 9 hrs., normal 9 hrs.; both macromere and micromere contain mitotic figures with many poles and scattered chromosomes; sphere granules at the animal pole of the micromere.

Fig. 200. Exp. 833: 2 per cent. $MgCl_2$, 9 hrs., normal 9 hrs.; resting stage following a division stage like that of the preceding figure.

Fig. 201. Exp. 838: Herbst's Ca-free sea water, 18 hrs.; micromere and macromere containing many nuclei and cytasters.

Fig. 202. Exp. 825: 2 per cent. NaCl, 16 hrs., normal 23 hrs.; two spheres and many scattered nuclei (karyomeres) in both macromere and micromere.

Fig. 203. Exp. 827: $\frac{3}{4}$ per cent. NaCl, 9 hrs., normal 8 hrs.; many asters and scattered chromosomes in the macromere and in one of the micromeres.

Fig. 204. Exp. 863: 2 per cent. NaCl, $2\frac{1}{2}$ hrs., normal 10 hrs.; similar to the preceding; scattered spindles and chromosomes; three small micromeres (lobes) budding off from the macromere; sphere granules at the animal pole of the micromeres.

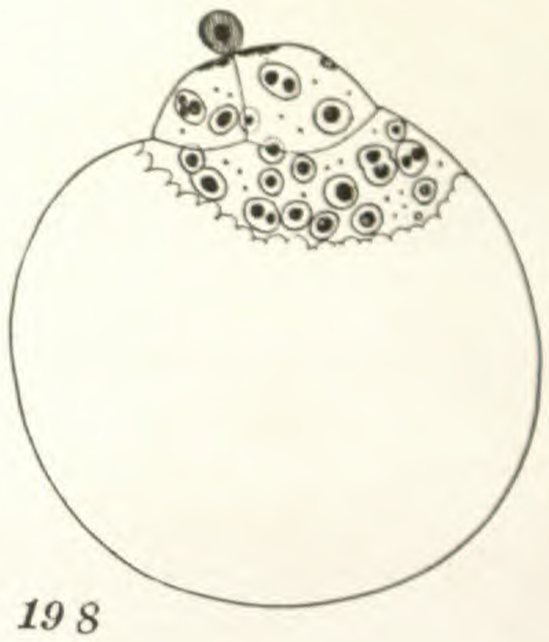
Fig. 205. Exp. 843: 1 per cent. NaCl, 6 hrs., normal 15 hrs.; several micromeres, three of them containing several nuclei or groups of chromosomes; the macromere contains many nuclei (karyomeres).

Fig. 206. Exp. 827: $\frac{3}{4}$ per cent. NaCl, 9 hrs., normal 8 hrs.; macromere and micromeres containing many karyomeres and asters.

Fig. 207. Exp. 830: 2 per cent. NaCl, 9 hrs., normal 32 hrs.; macromeres and micromeres containing a large number of karyomeres or asters; sphere granules under the polar body.

Fig. 208. Exp. 833: 2 per cent. $MgCl_2$, 9 hrs., normal 9 hrs.; many nuclei (karyomeres) and spheres in each cell.

197



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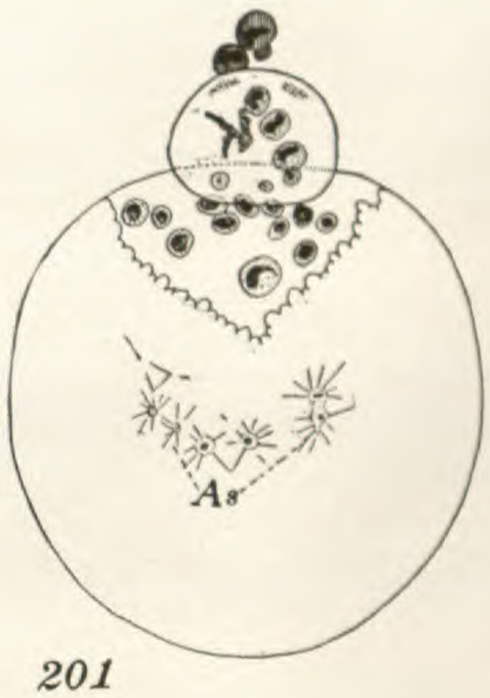

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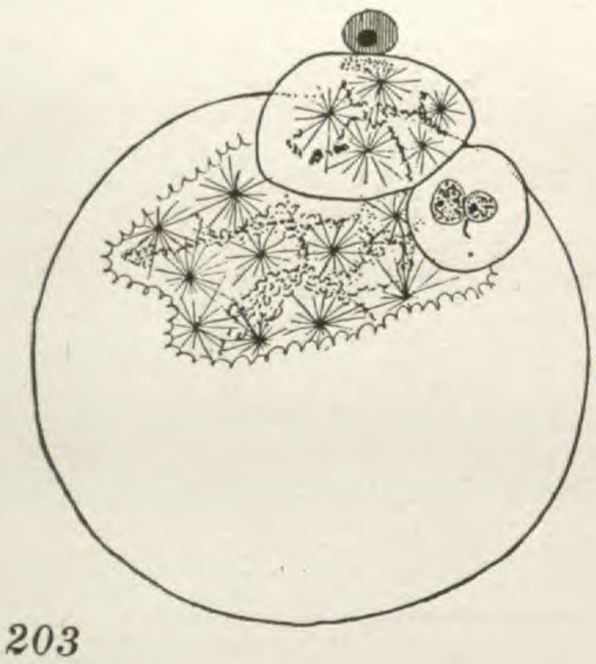

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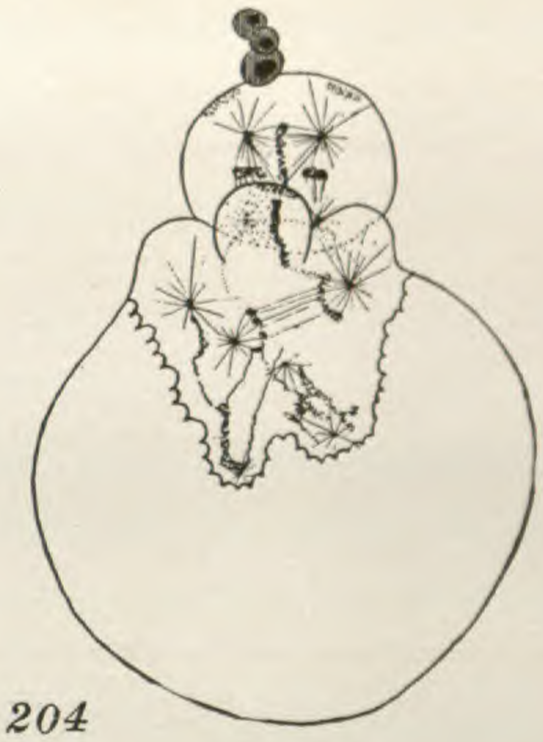

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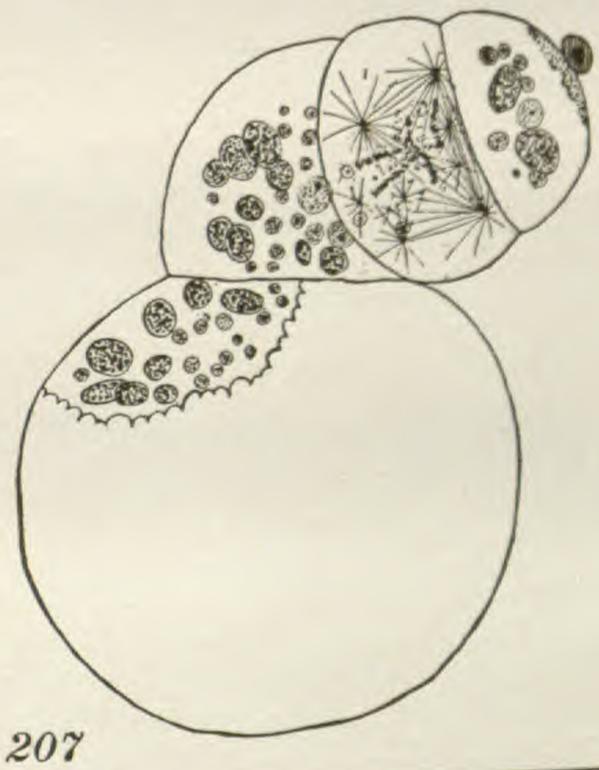

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Conklin del.

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

HYPERTONIC SEA WATER

PLATE LIX.

Effects of Hypertonic Sea Water.

Eggs represented in figs. 209–218 were in the 2-cell stage when the experiments began, and in none of them did the yolk undergo any subsequent cleavage; figs. 219–223 were in the 4-cell stage at the beginning of the experiment.

Fig. 209. Exp. 865: 4 per cent. NaCl, 2 hrs., normal 10 hrs.; the nuclear division at the 2d cleavage occurred regularly but the cell division was suppressed, thus leaving two nuclei of normal appearance, in each cell; at least three spheres are present in the left cell.

Fig. 210. Exp. 804: 1 per cent. NaCl, 4 hrs.; partial suppression of the 2d cleavage furrow which is limited to a shallow furrow on the animal pole side of the egg; the nuclei are irregular and densely chromatic.

Fig. 211. Exp. 864: 3 per cent. NaCl, 3 hrs., normal 10 hrs.; the 2d cleavage spindles have the position of the 3d cleavage spindles of normal eggs; the chromosomes are scattered abnormally on the spindles.

Fig. 212. Exp. 865: 4 per cent. NaCl, 2 hrs., normal 10 hrs.; the two macromeres have each given off a first and a second micromere, the first by dexiotropic and the second by læotropic division, as in normal eggs. Each of the first micromeres contain a single nucleus and sphere; the second micromeres and the macromeres contain several spheres and karyomeres or groups of chromosomes.

Fig. 213. Exp. 863: 2 per cent. NaCl, 2½ hrs., normal 10 hrs.; the first set of micromeres have been formed in dexiotropic direction, as in normal cleavage; the macromeres are dividing again with double spindles or tetrasters.

Fig. 214. Exp. 846: 4 per cent. $MgCl_2$, 4 hrs., normal 16 hrs.; the two macromeres are separated by a group of micromeres which have formed along both sides of the 1st cleavage plane; the polarity of each half thus appears to have been changed, the centers of the ectodermal pole being the surface of contact between the two halves; this may be due, in part, to the outward rotation of the macromeres at the vegetal pole and their inward rotation at the animal pole.

Fig. 215. Exp. 846: 4 per cent. $MgCl_2$, 4 hrs., normal 16 hrs.; side view of an egg with two macromeres and six micromeres; the two original micromeres of the first set have subdivided as indicated by the arrows, the other two micromeres are of the 2d set; all the micromeres contain karyomeres; the macromeres contain chromosomes scattered apparently, along the line of the 1st cleavage spindle.

Fig. 216. Exp. 846: Egg from same experiment as the preceding; the nuclei at the vegetal pole are probably derived from chromosomes which were scattered along the first cleavage spindle as in fig. 215.

Fig. 217. Exp. 822: 2 per cent. NaCl, 16 hrs., normal 8 hrs.; irregular and unequal 2d cleavage with several karyomeres of varying size in each cell.

Fig. 218. Exp. 842: 4 per cent. $MgCl_2$, 5 hrs., normal 17 hrs.; the divisions of the cell body at the 2d cleavage were suppressed in the left half, but two micromeres are arising in normal manner from this half; several accessory asters are present in this half which have served to scatter the chromosomes. The right half of the egg is quite normal.

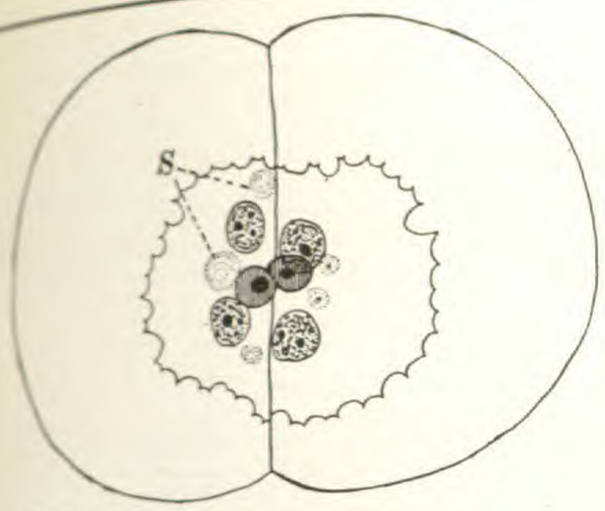
Fig. 219. Exp. 867: 8 per cent. $MgCl_2$, ¾ hr., normal 6½ hrs.; the 3d cleavage was very irregular and has given rise to a large number of karyomeres, and spheres which are in division in three quadrants of the egg.

Fig. 220. Exp. 972: 2 per cent. NaCl, 16 hrs., normal 24 hrs.; second quartet formation; karyomeres or polyasters in each of the cells.

Fig. 221. Exp. 814: 2 per cent. NaCl, 1 hr., normal 17 hrs.; second quartet formation; karyomeres and spheres in every cell.

Fig. 222. Exp. 828: 1 per cent. NaCl, 2 hrs., normal 6½ hrs.; second quartet formation; karyomeres and polyasters in every cell.

Fig. 223. Exp. 972: 2 per cent. NaCl, 16 hrs., normal 24 hrs.; karyomeres (and asters) in every cell; all nuclei are vesicular and contain achromatin as well as chromatin.



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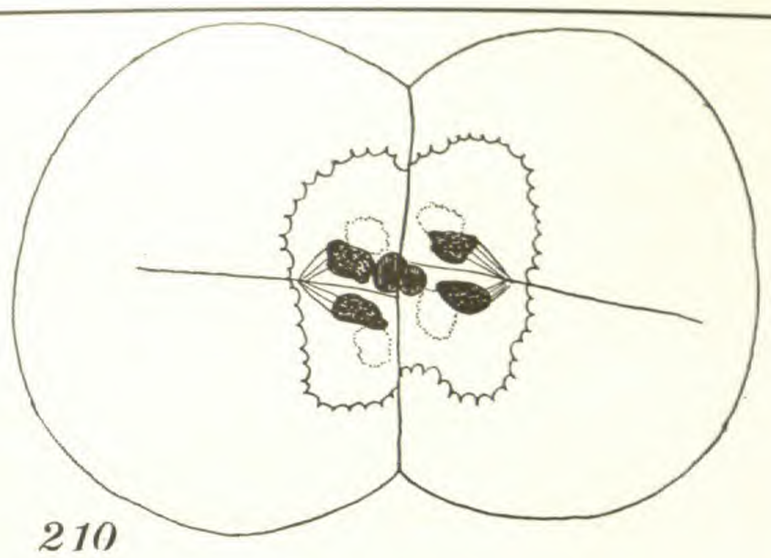

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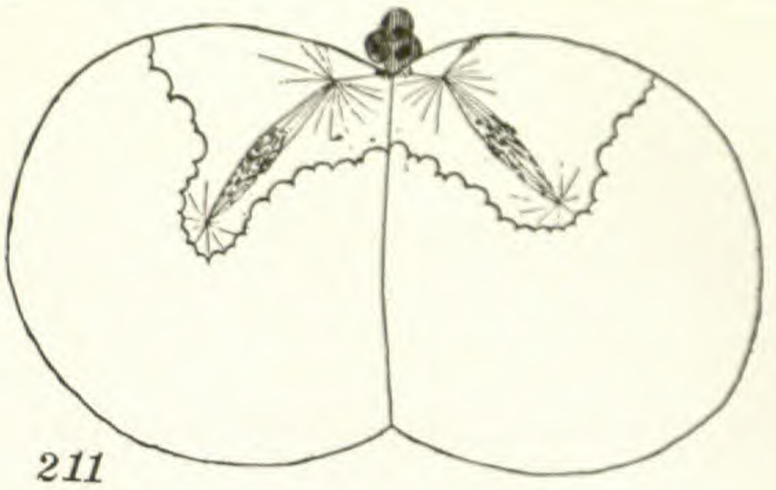

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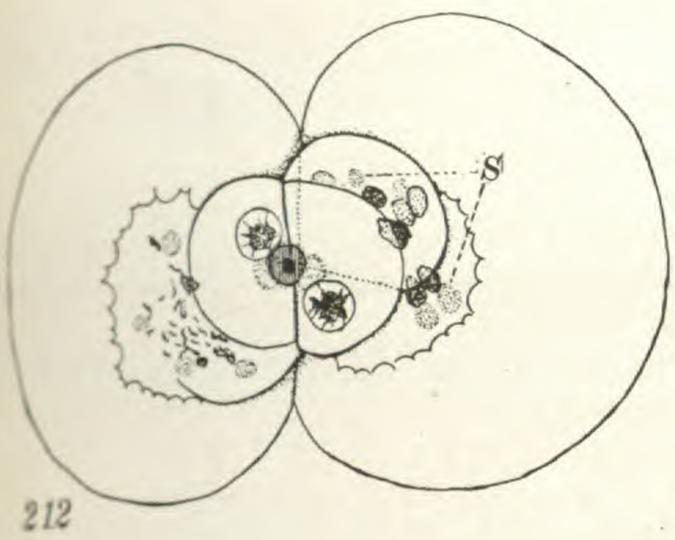

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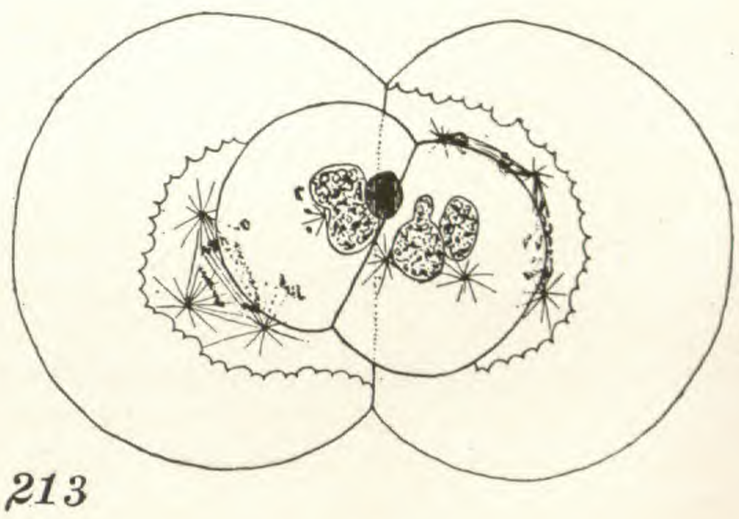

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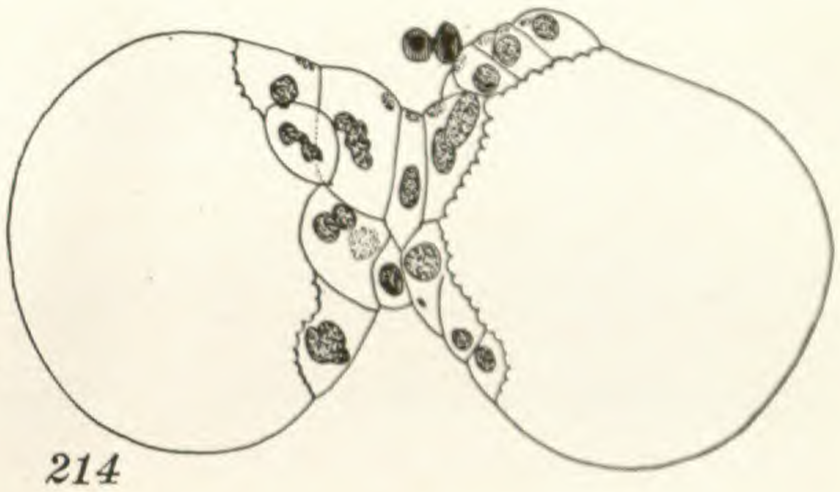

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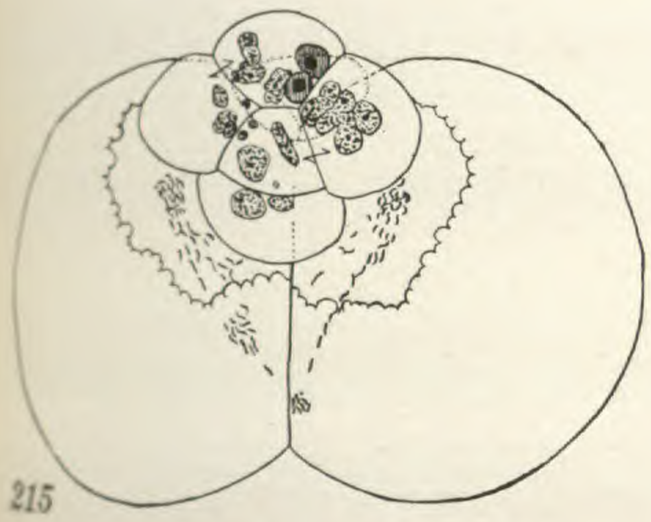

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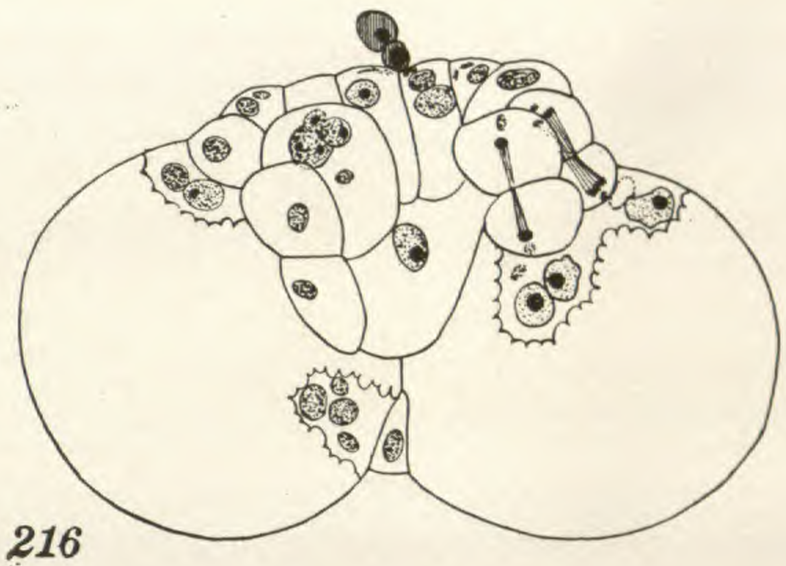

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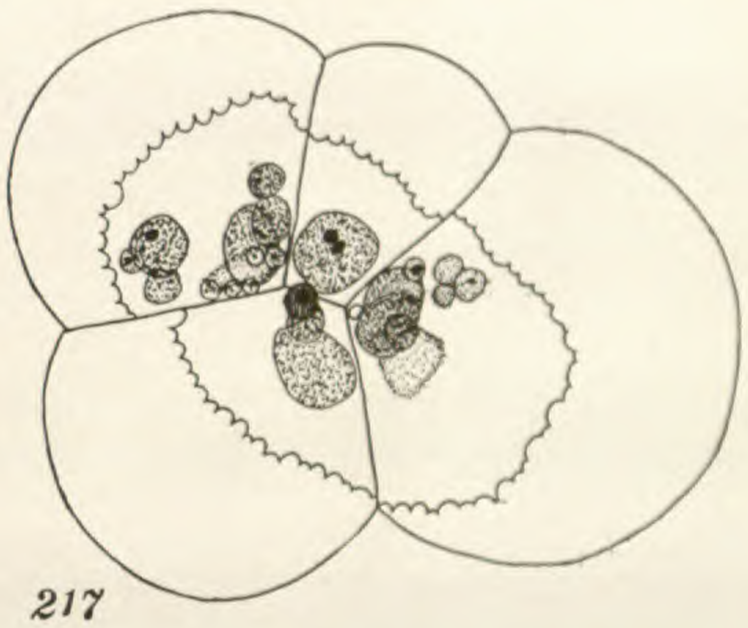

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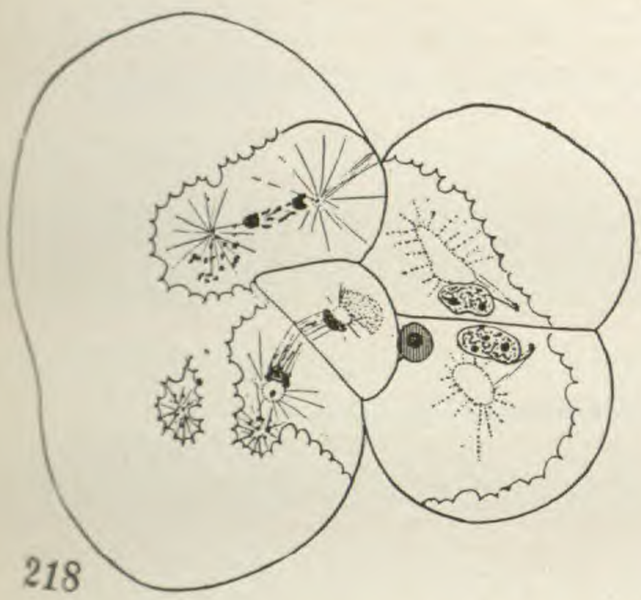

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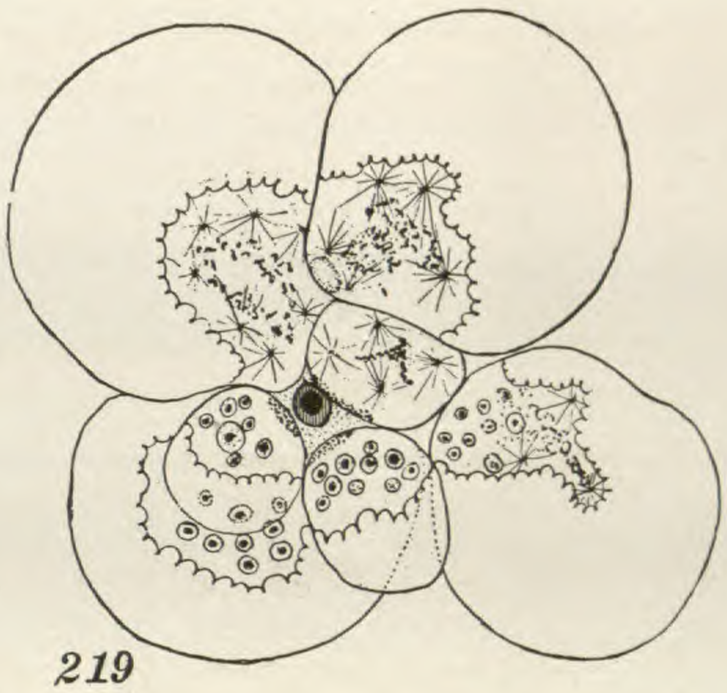

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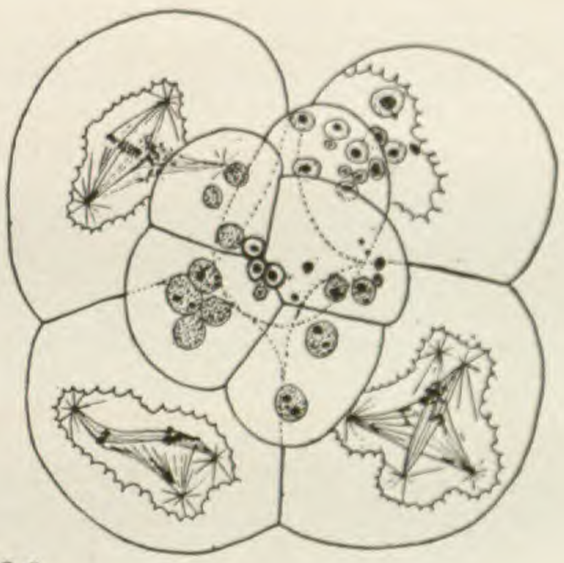

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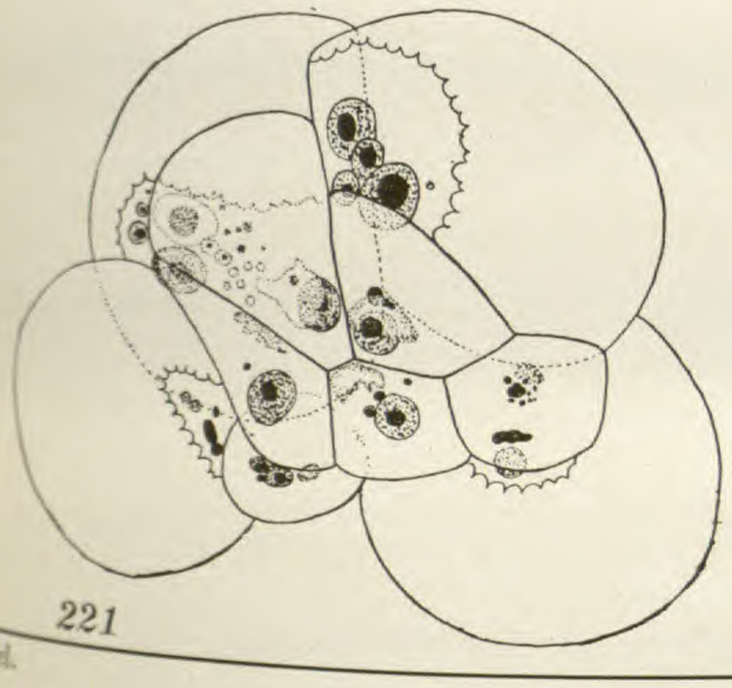

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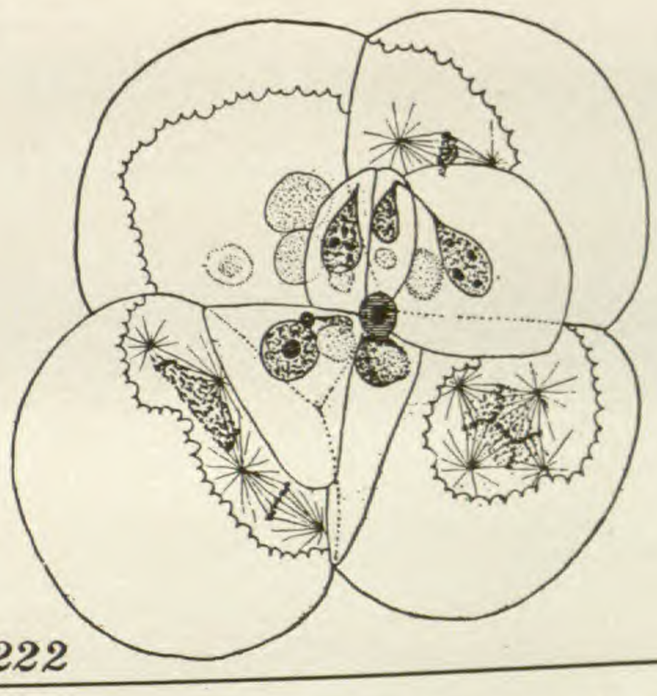

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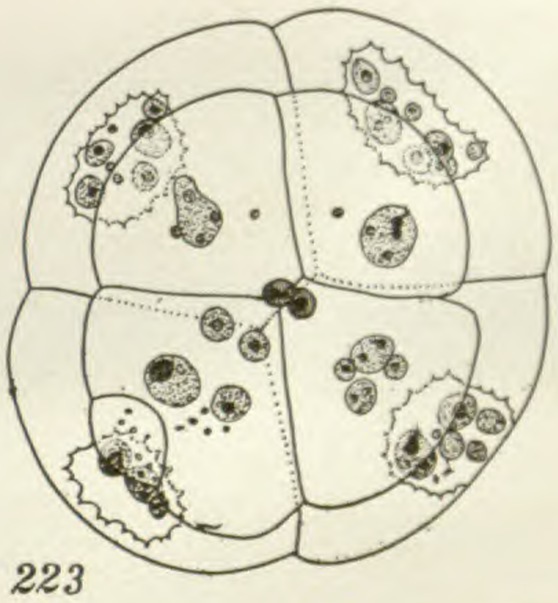

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Conklin del.

CONKLIN: NUCLEAR AND CELL DIVISION IN CREPIDULA

HYPERTONIC SEA WATER

INDEX TO GENERA, SPECIES, ETC., DESCRIBED OR REFERRED TO IN THIS VOLUME.

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